# DISCOVERY


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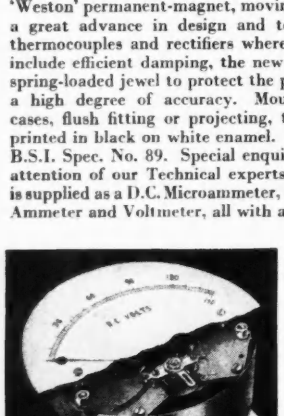

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# DISCOVERY

THE MAGAZINE OF SCIENTIFIC PROGRESS

**August, 1949** Vol. X. No. 8

Editor WILLIAM E. DICK, B.Sc., F.L.S.
Editorial Office: 244 High Holborn, W.C.1. Tel. Chancery 6518
Advertisement Office: 161 Cheapside, E.C.2. Tel. Met. 9729
All Subscriptions, Distribution and Business Communications to Jarrold & Sons Ltd., Norwich. Tel. Norwich 25261


# The Progress of Science

## Priorities for International Medicine

THE second World Health Assembly, held in the fifteenth-century Palazzo Venezia in Rome on June 13, discussed matters of great importance to ordinary men and women in every part of the world; and ordinary men and women should know about its plans for the future, because, as the World Health Organisation (WHO) *News Letter* says in its June issue, the campaigns initiated by the Assembly against the world's most dangerous diseases will succeed only if the men and women in the street realise their responsibility for their own health and that of their fellow human beings. The success of all health schemes depends upon the willing and constant co-operation of the individuals for whose benefit they are designed. It is futile, for instance, to have a British National Health Scheme if the British public are not willing to support it and play the game by trying to keep fit. The wise and beneficent plans of the second World Health Assembly will not succeed unless people all over the world do their bit in the world-wide fight against the major menaces to the health of the human species.

But how are we all to do our bit? We are not experts and we do not know what the most serious world diseases are, nor how to combat them. Nobody realises this better than WHO and its educational plans are a prominent feature of the programme discussed in Rome. These plans are based on the view that it is better to show people how to get healthy and how to prevent the occurrence of disease than to put up, in each country, expensive safeguards against the diseases prevalent in each locality. These safeguards will be needed, of course, but, if people are taught more about the causes of disease and how each disease spreads, and if, at the same time, vigorous efforts are made to eradicate reservoirs of the major diseases of the world, there will be less and less need for heavy capital expenditure on fever hospitals, quarantine stations and similar weapons now employed.

The Assembly in Rome therefore discussed, for the first time, this approach to the problems of world health. The plan is to concentrate attacks on parts of the world where endemic disease, poor sanitation, bad housing, inadequate diets and unhygienic life all help to perpetuate reservoirs of certain diseases, such as cholera, typhus, and malaria, from which infection can spread continually to other parts of the world. Its spread by every kind of agency is to be combated; and, among these agencies, high priority will be given to the aeroplane and other means of rapid international transport. At the same time plans are being discussed for the despatch of teams of trained personnel to areas which are reservoirs of disease, in which the latest methods of fighting these diseases would be demonstrated by the teams. These Health Demonstration Areas, as they are called, would become centres from which wider regions around them could be taught how to fight disease and attempts to eradicate diseases would proceed along with these educational activities. Venereal disease, mental health, maternal care and child health are included with the other diseases mentioned in this article in the educational and demonstration programmes under discussion.

While the elimination of the suffering and inefficiency caused by disease in many parts of the world is one of the main aims of the Assembly's programme, it is realised that one of the chief weapons against disease is the provision of adequate supplies of human food and the right kinds of food. Everyone knows that the world is threatened with a food-shortage, but many people do not realise that the world's food-production could be higher if the people in many potential food-producing areas were in better health and therefore could work better and more happily. Malnutrition is regarded by some experts as being the most serious menace to health in the tropics and the Assembly's plans to deal with it should be supported vigorously. In the Terai foothill region of India, for instance, 'foothill malaria' has practically stopped cultivation of a potentially productive soil. A vigorous, world-wide attack on the parasites of farm crops and domesticated animals would reduce the enormous losses at present inflicted by these parasites.

Malaria is, of course, responsible for incalculable loss of efficiency in every country in which it is prevalent. Rightly it has been called the world's most serious epidemic disease and everyone will commend the vigorous campaign against it planned by WHO. Great advances in its control were made during the recent war, by means of drugs given to individual sufferers and by attacks on the anopheline

mosquitoes which transmit it. Years ago, when the fact that female mosquitoes of the genus *Anopheles* transmit malaria to man was proved, no less an authority than Sir Ronald Ross declared that it would be impossible to rid large tracts of tropical country of these mosquitoes. But the successful eradication of *Anopheles gambiae* from Brazil, to which country it was carried by fast destroyers and probably also by aeroplanes and caused between 1930 and 1940 one of the most severe outbreaks of malaria known to history (see DISCOVERY, February, 1946), showed that determined and well-planned team action can eradicate a mosquito from country of the most difficult kind. The team which accomplished this amazing and historic feat repeated their success in Egypt and nowadays, armed with DDT, BHC and other insecticides developed during the recent war, malaria is being attacked with ever-increasing success. Anopheline malaria-carrying mosquitoes have been almost entirely eliminated from the islands of Sardinia and Cyprus and similar successes have been recorded in other areas. As the WHO *News Letter* says, it is now for the first time possible to see ahead a world free from the malaria which has been for so long one of its major scourges.

Malaria is a good example of a disease caused by a parasitic animal and dependent upon a parasitic insect for its transmission to man. Another example is trypanosomiasis (African sleeping sickness), the trypanosomes which cause it being transmitted to man by tse-tse flies. Some species of trypanosomes cause a form of sleeping sickness in domesticated animals, and thus affect human food-supplies. Confined as they are to Africa and central and tropical South America, the most harmful trypanosomes have wiped out entire tribes and have prevented pastoral development. The recently discovered drug antrycide may enormously increase our control of trypanosomiasis, but the campaign planned by WHO against these parasitic animals is urgently required.

Another group of parasitic animals which cause incalculable misery and inefficiency among human populations, and in domesticated animals also, are the parasitic worms. Of these the roundworms cause the greatest harm. Bancroft's filariasis, for instance, which may cause the swelling and thickening of parts of the body called *elephantiasis*, is transmitted to man by mosquitoes, and in Asia, Africa, Central and South America and the islands of Oceania it affects 190 million people. It has been estimated that a third of the population of the world are infected with filarial worms of some kind. The disease caused by other roundworms is not dependent upon mosquitoes or on any other vector and their control is comparatively simple. The hookworms, for instance, which cause appalling suffering in many warm countries, are practically confined to man, so that human infection always comes from other human beings, and it could be prevented entirely if every human being in the areas in which it is prevalent practised quite simple and ordinary care in the disposal of human excreta. Schistosomiasis (Bilharzia disease) is less readily controlled; it is caused by three kinds of worms related to the liver fluke of cattle and sheep, which live in the blood-vessels of man and cause a prolonged and crippling disease. It is estimated that 150 million people suffer from this disease and that, in some parts of the American, Asiatic and African continents in which it occurs, as many as 90% of the rural populations may be infected with it. Schistosomiasis depends, like liver-fluke disease of sheep and cattle, upon certain aquatic snails, in which the blood-flukes must live part of their lives. They eat the young blood-flukes which come out of eggs passed out in human excreta, and later more mature flukes come out of the snails into water which infects human beings with the flukes when they drink it. If infection came only by drinking such infected water, control of the disease would be effected by boiling all drinking water; but the young flukes can, like young hookworms, bore through human skin, so that even washing the hands in infected water may result in infection and control is therefore difficult. The surest guard against the disease is the destruction of the snails; but that, like the destruction of the mosquitoes which carry malaria, or the tse-tse flies, is not an easy task.

Apart, however, from these diseases caused by parasitic animals, diseases caused by bacteria and viruses were attacked by the experts gathered at the Palazzo Venezia. Among these were tuberculosis and venereal disease. The lines of attack on tuberculosis are extensive trials of vaccination with BCG vaccine of children not infected and the finding of infected people by means of examinations of the chest by the microfilm method. Another valuable line of attack would be a vigorous attempt to repeat all over the world the virtual eradication of tuberculosis from cattle achieved in the United States. Leprosy, which causes so much suffering to millions in the tropics is also to be vigorously attacked. Three diseases caused by viruses are to be attacked, namely, infantile paralysis (poliomyelitis) which exists practically all over the world; the disease of the eyes called trachoma, which often leads to blindness and is present in 90% or so of the 20 million people of Egypt; and rabies, which is not by any means confined to 'mad' dogs, but affects also other animals, domesticated and wild. Children are to be defended by intensified action against diphtheria, whooping cough and measles, which are, in temperate zones, the chief causes of death among children before school age.

Much of the work of WHO under discussion by the Assembly has been taken over from the League of Nations. In this category come work on the maintenance of international standards of drugs, vaccines, antibiotics such as penicillin and streptomycin, and the preparation of international health statistics. Nor is the shortage of trained personnel being neglected. Both doctors and their assistants are needed. North America, Europe and the U.S.S.R. have about one doctor to every 1200 people and Latin America, South Africa, Australia, New Zealand and Japan have about one doctor to every 1700 people. The rest of the world, however, which includes most of Africa and Asia, in which more than half the world's populations live, often under poor nutritional and social conditions, and in which many serious epidemic diseases have their roots, has only one doctor to every 12,000 people.

It would be hard to find aims more beneficent and more urgent than those embodied in the Assembly's programme. Its plans, if they can be brought to success, will have incalculable effects upon the future of a world which is, in spite of political delays, inevitably becoming a unity. They will increase the world's food supplies, substitute happy self-supporting people for the millions who are now badly nourished, ill and unhappily dependent. But the task of the

WHO is not an easy one. It will not be done unless ordinary human beings all over the world are willing to help by learning how to keep fit, how to avoid infection with disease and how to help the other fellow to work to the same end.

## Metre, Gram and Litre: 150 years

WITH most events in the history of science it requires some mental effort to decide what is their significance for us. Not so with one event of 150 years ago, the introduction of the definitive metric system—for every scientist meets daily mementos of it every time he measures or weighs. The introduction of a rational system of weights and measures, based on decimal divisions, was probably one of those things that could only happen in a revolution. Scientists, industrialists and merchants had often expressed a desire for a rational system. But to obtain it would imply far-reaching changes, producing temporary change-over difficulties in most walks of life. In times and places where those who controlled the affairs of state were content with the *status quo* or saw progress as a slow and unplanned process, they were not prepared to face these difficulties. Then came the French Revolution, and with it a strong desire to improve anything that could be improved by legislative action, and a willingness to face short-term difficulties in order to obtain long-term benefits.

The problem of weights and measures was much more acute in France than in England: that country did not merely have to contend with *an* irrational system, but with a diversity of irrational systems in various districts. It happened that in 1788, the year before the Revolution began, a commission consisting of such eminent scientists as Laplace, Lagrange, Monge, Condorcet and Borda published a report on the choice of a unit of measure, recommending in effect the metric system. In the revolutionary year of 1789 many of the *Cahiers de Doléance* (statements of grievances drawn up by the people in most parts of the country) demanded the establishment of a uniform system for the whole country. Despite the troubles and turmoil of revolution, and the very pressing need to defend it against attacks from the old order, the National Assembly and its successor, the Constituent Assembly, found time to discuss these proposals. And in 1791 the proposal to establish the metric system was approved. In order to make the new system truly international (for internationalism was one of the strong points of the Revolution) it was decided to avoid all local standards and to base the system on the definition of the metre as one-ten-millionth part of the quarter of the earth's meridian. Measurements of the meridian were then in a chaotic state. It was therefore necessary to carry out an entirely new survey. The main operation was a measurement of the arc between Barcelona and Dunkirk, which was carried out by Delambre and Mechain between 1792 and 1798. This survey was one of the most important steps in modern geodesy, and the scientific work connected with it was responsible for a number of other scientific advances. For example, it led Legendre to the discovery of a formula reducing the calculus of spherical triangles of small curvature to that of plane triangles. And the enormous calculations connected with the survey led to the development, under the supervision of Prony, of new methods for the organisation of computational work carried out by a large staff.

A provisional metric system was introduced in 1795, but the true beginnings of the system date from 1799, when the geodetic work had been completed and the definitive metre was introduced. There were, of course, many difficulties still ahead. The long-used units could not be abolished by a legislative stroke, and a practical compromise, the *système usuel* was in use for everyday purposes until 1840, when the metric system became obligatory. Other countries were converted with varying speeds until today the metric system is in universal use for scientific purposes and outside the world of science the English-speaking countries are virtually the only ones that do not use it.

## Reading Aids for the Blind

EVERY DAY the division of science into separate subjects becomes less and less realistic. In the June 1949 issue of DISCOVERY (pp. 171–3) we published a note which showed, among other things, how advances in electronic calculating machines are helping to throw light on problems of psychology. In passing we also noted how an attempt to construct a reading machine for the blind suggested a possible solution for one of the most fundamental problems of psychology. This month we can complete the triangle with a case in which devices derived from electronic calculators promise improved reading aids for the blind. It is reported in an article, "Research on Reading Aids for the Blind" by V. K. Zworykin, L. E. Flory and W. S. Pike in the *Journal of the Franklin Institute* (May 1949, pp. 483–96).

The device that we referred to in June is essentially one that substitutes the *sense of hearing* for the *sense of sight*. An eye scanning a line of type through a narrow vertical slit that moves horizontally across the type would see at every stage one or more black dots at various heights in the slit. As the slit moves, the dots would appear and disappear and slide up and down. And with practice one could learn to interpret these movements, to deduce what letters are passing under the slit and so to read. The device for helping the blind simply translates the dots that appear in the slit into musical tones—high tones for dots near the top of the slit, low tones for those near the bottom. And again with practice one could learn to deduce from these sounds just what letters are being scanned. The apparatus mentioned in June was a crude proposal for doing this, but more refined methods are described in the article now under reference, and it has been proved that with the aid of these a blind person can read at least twenty words a minute.

The essential point about such devices, however, is that they only translate one set of sense data into another—instead of a line of print, the reader is provided with a succession of sounds. He has then to interpret the sounds, turning them into letters, then words, and finally sense. And a succession of sounds is more difficult to interpret than a visual line of print—as we all know when we try to appreciate in its fulness a Bach fugue. Zworykin and his associates describe an experimental apparatus which carries the aid a stage farther. It scans the line of type as before, but now it takes account of the succession of dots

in the scanning slit, recognises the letter they represent and having done so says the letter aloud—so that the blind reader is left with the comparatively simple task of building the letters into words and thence into sense.

To get an idea of how this device works, let us first imagine that the scanning slit is stationary. The scanning (done by a light spot and photo-cell) is in this case not continuous and simultaneous. Instead the spot scans eight successive points in the slit, starting at the bottom and working upwards. Thus if the slit happened to be over a letter *l* the scanner would give eight 'blacks' in succession. But if it were over the middle of an *o*, it would give something like 'black, three whites, black, three whites'. However, the slit moves over the type from left to right while the scanning spot moves up and down. So that a complete letter *o* would come out as something like: (left edge) white, three blacks, four whites; (middle) black, three whites, black, three whites; (right edge) white, three blacks, four whites. Actually the output of electric pulses corresponding to these observations would not be separated into left, middle and right groups, so that it would appear as simply WBBBWWWWBWWWBWWWWBBBWWWW.

Now it is clear that on being told that this succession of pulses had been put out one could deduce that the letter scanned was *o*. Similarly, if the pulses said BBBBBBBB WWWWBWWWBBBBWWWW, the letter must be *h*. A complication arises from the fact that the horizontal speed of the scanning slit may vary and the scanner will not necessarily read simply the two edges and middle of each letter. But one can still see how the more complex patterns of pulses that emerge in these circumstances could be interpreted to give the letters being scanned.

So, given time, a human brain could sort out the pulses coming from the scanner and name the letters they represent. The problem is, could a machine be designed to do this and to do it quickly enough? The answer is, Yes. Many electronic calculators incorporate a device, called a 'function matrix' which does precisely this sort of job. Its function is to receive certain patterns of pulses, examine them, distinguish one pattern from another, and then transmit output signals—a different output for each pattern—which denote just what pattern the machine has recognised. The whole process is done, of course, by a complex series of electronic switchings though these are simple in principle. So in this reading aid, the scanning device sends out a series of pulses (actually it sends a pulse for white and no pulses for black); these go to the function matrix which proceeds to disentangle the pulse patterns; and having recognised, say, the letter *b*, the function matrix sends a signal to another part of the machine which plays a sound recording of 'bee'. And so the reader hears the letters spelled out one at a time.

So far the device has had only laboratory tests. Using a very plain sanserif type, it has proved to be fully reliable. But it demands very stringent alignment of the scanner, and its tolerance in this respect will have to be improved. And clearly its usefulness will be greatly restricted unless the 'intelligence' of the function matrix is raised high enough to enable it to deal with a variety of types.

There is another intriguing possibility. Spoken English with quite a high degree of shading can be built up from some thirty or forty phonetic sounds. If books were printed in a phonetic alphabet corresponding to these sounds, the reading device could be so designed that it would respond to the text by reading it aloud in some approximation of the actual English words.

## Rhenium

DISCOVERED a quarter of a century ago the element rhenium still remains rare. Relatively few people have yet seen or used it and there is no known mineral that can be called an ore of rhenium. At first it was supposed that the richest sources contained no more than a few parts per million and elaborate colour tests were devised to detect and determine the amount of rhenium in certain rare earths like gadolinite and in some sulphide ores like copper pyrites. Hopes of a reasonable supply of the element for experimental purposes were raised when it was found, in 1930, that rhenium accumulated in certain waste sulphide residues during special metallurgical refining processes. From these sources enough became available for it to be possible to make a thorough study of the properties of the element and over a hundred of its compounds, some simple others quite complex, are now known. The commonest compound is potassium perrhenate which, like rhenium itself, is today a commercial product.

Since the last war it has been discovered that some molybdenum ores are particularly rich in rhenium and some contain as much as three parts per thousand of the rare element and from them it can be profitably extracted. Chemical curiosities of yesterday may easily become vitally important substances tomorrow and it is now known that any use for which rhenium is required could therefore be met as soon as the need arises, at least as far as twenty or thirty pounds of it are concerned.

To the physicists rhenium is known as the element of atomic number 75 and it falls into group 7 of Mendeléef's Periodic Table. Its existence was predicted by Mendeléef as long ago as 1871 and he provided for its eventual discovery, provisionally calling it *dvi-manganese* (*second below manganese*). Actually it does not particularly resemble manganese since only in its free state does it behave like a metal. In chemical properties it is rather similar to molybdenum and unless it proves to be superior to molybdenum in some special way it may not find extensive applications.

On the experimental and semi-technical scale it has been shown to be a useful catalyst in the hydrogenation of unsaturated hydrocarbons and of carbonyl compounds. It is also capable of the dehydrogenation of alcohols, thereby producing aldehydes and hydrogen. Coatings of rhenium on tungsten, copper, nickel and other metals are expected to find uses in constructing certain valves whilst its resistant properties have led to a suggestion for using it as electrolytic coating on metals, notably silver.

# The Hazards of Radiation

P. C. KOLLER, Ph.D., D.Sc.

We entered the 'atomic age' on the day the nuclear chain-reaction was started. Vast laboratories are planned and being built, or are already in operation, and the number of workers engaged in the attempt to harness atomic energy increases daily. Radioactive substances are produced in quantities hitherto undreamed of, and placed in the hands of chemists, physicists, biologists and doctors for use in their respective fields. Even in 1947, Dr. P. C. Aebersold, head of the division of the United States Atomic Energy Commission dealing with radio-isotopes, was able to state with confidence that "almost every useful isotope which is found in Nature or producible by man is now available for the investigator. Advance in biology and medicine through the use of isotopes will henceforth be limited only by the availability of personnel and facilities and by the imagination of the investigators."

The vast expansion of research in the field of nuclear energy necessarily increases the hazards which are associated with the handling of radioactive substances and high-energy generators. That ionising radiations, such as those produced by X-rays or radium, can be injurious to the health of the user has been known almost since these radiations were discovered. When the number of fatalities due to ignorance or indifference showed an alarming increase, protective measures had to be devised and enforced in hospitals and other institutions to safeguard those working with X-rays, radium or other radioactive substances.

With the recent developments in high-energy radiation the problem of protection became of special importance, owing to the fact that the amount of gamma rays, fast and slow neutrons emitted in the chain-reaction is so great that the standard protective measures which were previously sufficient to guarantee safety cannot now be trusted.

Since the end of the last war, the scientific literature is being enriched almost daily with reports dealing with radiobiological research in which the diverse effects of the new radiation sources are under scrutiny. Conferences are frequently held to discuss the various aspects of the protection necessary when handling radioactive material, which is a sign that we have become aware of the risk that is associated with the century's greatest discovery. The risk is great, perhaps too great; it may even prevent us from enjoying the fruit itself. In the present article I wish to discuss the nature of injuries induced by radiant energy and their origin and detection, in order to show the magnitude of the task which lies before us.

## Radiobiological Research

Barely one week after Roentgen's lecture in which he described the properties of X-rays, a letter was published in the *Lancet* which suggested that these rays may have destructive effects on single-celled organisms, such as the bacilli of tuberculosis and diphtheria. At that time it was no more than a suggestion, but within a few months it was brought home only too forcibly that X-rays could produce very drastic effects on living tissues. Many of those who experimented with the rays developed lesions or 'X-ray burns' on their hands which had been exposed, and not a few of these became martyrs in the cause of the progress of science. With the discovery of radium the effect of radiation on living matter could be controlled and studied more satisfactorily, and for that purpose in 1906 the first "Biological Laboratory of Radium" was founded in Paris. This Institute was not only the pioneer laboratory in this field but it became the centre of the most interesting experimental research in radiobiology. Intensive studies of irradiated tissues were carried out there and it was soon discovered that the rays of radium have a selective action on tissues and cells; some living matter (e.g. bone-marrow, tumour cells) was found to be destroyed by much smaller doses than were harmful to others.

In order to obtain more exact information about the mechanism by which radiation acts upon living matter, and to control the extent of radiation injury, experiments were carried out on a large scale; almost everything living was placed in the beam of rays. Such diverse 'biological indicators' as bacteria, infusoria, yeast and mould; fern and pond-weed; pollen, seed, root and stem of bean and onion; egg, sperm and larva of fly and star-fish; toe and heart of frog and salamander, sperm of rat and cat; blood of mouse; eye of tadpole and rat; skin of man; all have been used—indeed a regular witch's brew. The confusion and contradiction of the results obtained by the investigators can now be easily explained; for most of the effects measured and compared were not immediate and initial effects, but end-products of a chain of reactions set in motion by the radiation. It became obvious after enormous labour and effort had been expended that the changes observed in the whole organism, organs and tissues had to be traced to the initial changes induced by the radiation in the cells themselves which build up the tissues, organs and organism, and these changes had to be studied in order to understand the basis, and estimate the magnitude, of radiation injury.

## Ionisation

Before discussing the effects produced by radiation within the cell, it is necessary to describe the mechanism by which radiant energy becomes effective within living matter (Table I). Various hypotheses were put forward to explain the primary effect, the first step in the chain of events which leads to a significant (often fatal) change in behaviour and structure of the cell. The most acceptable working hypothesis is that which attributes the effect of radiation to '*ionisation*'. According to this hypothesis the ionising particle which is emitted from the X-ray tube, radium, cyclotron, etc., passes through atoms, until it meets an electron in a collision, which will then be ejected. An atom which has lost an electron becomes positively charged, and it is referred to as an '*ion*' and the process as '*ionisation*'. The electron, which has been ejected, is called the '*secondary electron*' and behaves like the original or primary ionising particle; it, too, passes through other atoms, colliding with their electrons and pushing

TABLE I

The various types and sources of radiation

| *Radiations* | *Source* | *Ionising Particle* |
|---|---|---|
| Beta<br>Gamma<br>X-rays | Radium<br>Radio-isotopes<br>Betatron<br>X-ray tube | Electron |
| Neutron | Cyclotron<br>Atomic pile | Proton |
| Alpha-particles | Radon | Alpha-particle |
| Nuclear-fission Products | Atomic pile | Nuclear-particle |

TABLE II

The approximate number of ion-clusters along the track of the various particles

| *Radiation* | *Particle* | *Number of ionisations per micron* of tissue* |
|---|---|---|
| Beta<br>Gamma<br>X-rays | electron | 8–100 |
| Neutron | Proton | 300–1200 |
| Alpha-rays | Alpha-particle | 3700–9000 |
| Nuclear fission | Nuclear-particle | 130,000 |

*Micron ($\mu$) = 0·001 millimetre.

them off; in other words, it creates other ionisations along its path. The energy of ionisation is conducted along intra-molecular bonds, and often the bonds which hold adjacent atoms together become broken. This is the reason why, when an atom is ionised, the molecule of which it forms a part undergoes chemical change. We may mention that the ionising particle can transfer energy to an electron without pushing it off completely from the parent atom; in such a case the atom becomes only 'excited'.

There are four kinds of ionising particles; these are: the electron, proton, alpha and 'nuclear' particle. These particles are produced by various generators, and they differ in size, charge, speed, and behaviour (Fig. 1). The properties of the 'nuclear' particles of nuclear fission are still shrouded in mystery.

The biological effects, i.e. changes induced in any living matter (e.g. inactivation of viruses, mutation of genes, fragmentation of chromosomes, destruction of cells and tissues, cessation of growth, etc.) can be attributed to ionisation of molecules in the path of the various ionising particles. Owing to their different properties, the efficiency of the various radiations differ, and there is a great deal of evidence that it is conditioned chiefly by the spatial distribution of the ions along the track of the ionising particle (Fig. 3). The spacing of ionisation can be studied in the Wilson Cloud Chamber. The principle of this piece of equipment is simple; before the passage of the ionising particle through the chamber, which is saturated with water vapour, a super-saturated condition is produced so that water condenses around each ion, and the track of the particle takes the form of a trail of fog which can then be photographed. The recent development of extra fine-grain photographic emulsions opened the way for a more direct study of the ionisation tracks (see Hertz, "The Photographic Plate in Atomic Research", DISCOVERY, March, 1947). We find by such methods that the ionisation occurs in clusters, separated by gaps in which no ions are formed, and that the speed of the ionising particle is greatly reduced towards the end of the track. With the loss of speed, the spacing of ionisation is altered too and becomes more crowded in the 'tail' of the track. Owing to variations in the spacing, we can only give the *average* ion-density of the various radiations (Table II).

The amount of radiation energy absorbed within a given volume and conveniently measured in *roentgens* is represented by the number of ionisations within the same volume*. When the dose is the same, the number of ionisations is the same also, though their distribution or spacing may be very different when different sources of radiation are used. It needs to be emphasised that the different density of ionisation along the track of the ionising particle is responsible for the fact that one kind of radiation is more efficient than another, i.e. a smaller dose is required to produce a given effect. We must mention here that the 'efficiency' of a radiation is relative; while radiation A may be more efficient than B for a certain biological

* One roentgen unit represents the production of about 3 ionisations per cubic micron. (The micron is defined in Table II.)

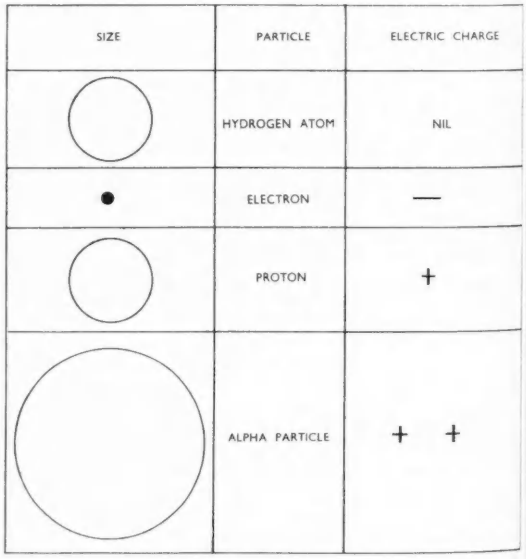



FIG. 1.—The size and electric charge of ionising particles are compared with the hydrogen atom.

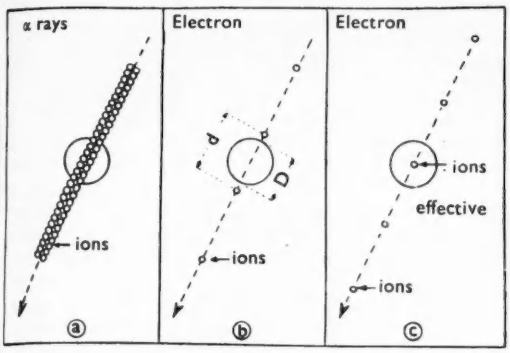



FIG. 2.—Diagram showing the biological efficiency of alpha particles and electrons acting on a virus. D = diameter of virus, d = distance between two adjacent ion-clusters (after Bonét-Maury).

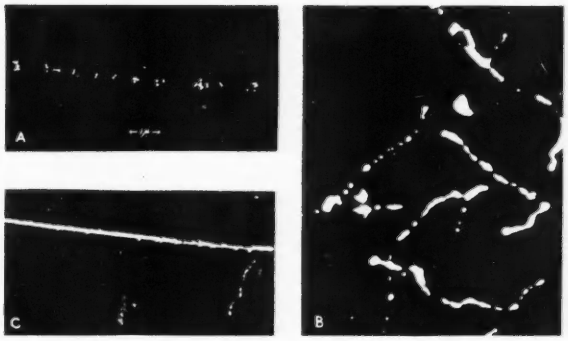



FIG. 3.—Wilson Cloud Chamber photographs of ion-tracks, (*a*) track of an electron of beta radiation, (*b*) tracks produced by electrons of X-rays, (*c*) track of an alpha particle. Ion density is expressed in terms of number of ionisations per micron (one-thousandth of a millimetre). (By permission of the Editor of *British Journal of Radiology*.)

phenomenon (such as the killing of a virus), radiation A can be less efficient than B in connexion with some other biological phenomenon (such as breaking of the chromosomes within the cell nucleus). This is actually the case when we compare the relative efficiency of X-rays and neutron radiation. The cause of this apparently parodoxical behaviour is discussed below.

The various ion-densities of different radiations for the inactivation of viruses is illustrated in Fig. 2. The spacing of ion-clusters in the path of electrons from gamma radiation and that of an alpha particle is compared and superimposed upon a volume representing a virus of 25mμ diameter (1 mμ = 1/1000μ). The virus may be looked upon as a big molecule, which reproduces by a simple chemical process. A change at almost any point in the molecule dislocates the smooth operation of the reproductive reaction and results in death or 'inactivation' of the virus. It seems—at least in the majority of the viruses—that the existence of the virus as a biological unit depends on the proper functioning of every atom. Ionisation, i.e. the loss of an electron, means a serious disturbance in the chemical properties of the affected atom and leads to disruption of the very closely knit structure of the virus. It is clear in the Figs. 2*b* and 2*c* that an ionising particle from gamma radiation rarely if ever produces more than one ionisation within a virus of that size, therefore almost every ionisation in a given volume will be effective. An alpha-particle on the other hand produces a great number of ion-clusters within the same virus. We have already mentioned that very few ionisations within the volume of the virus are sufficient to inactivate it; therefore, all the other ionisations are wasted—like kicking a horse which is already dead. It is obvious that in order to kill the same number of viruses a much greater number of ionisations, or larger dose, is required when alpha radiation is used. We may state, therefore, that for the inactivation of viruses alpha radiation is much less efficient than X-radiation. We can see that the inactivation dose is independent of ion-density for one kind of radiation, but not for others. The criterion is the distance between adjacent ion-clusters in relation to the size of the virus; if the latter is greater than the former, the efficiency of radiation depends on ion-density.

It is not out of place here to emphasise again that besides the hypothesis which attributes the biological effect to 'direct' action, there is another which assumes that the action is 'indirect'. According to the latter, which is specially applicable when complex cell-effects are considered, the action of radiation is brought about by the formation of active radicals in the water molecules, which are always present in large numbers in any living organism, $H^+$ and $OH^-$ ions being produced by the action of the radiation on the water molecules. The two hypotheses, however, are not mutually exclusive; they are complementary and similar in their fundamental concept.

Radiobiological investigations have provided ample evidence that in an organism a thousand ionisations may occur, 999 of which do nothing or their effect is temporary only, while the 1000th 'hits' the right spot and leads to profound changes in the organism, which may be death or permanent alteration in behaviour and structure. Such effects are numerous and they are proof that the life of the cell depends on atomic structures, many of which have 'key-positions' and when disrupted cannot be replaced.

It was already mentioned that in a small virus molecule every atom may be looked upon as an Achilles heel or a sensitive spot, and ionisation at any of these points leads to the disintegration of the whole system. As we pass from the small virus particle to larger viruses and to higher biological units such as the bacteria and the cell, the size of the *sensitive spot* or region becomes smaller and smaller *in relation to the whole unit* (Fig. 4).

## Radiation and the Cell

Now let us consider in some detail what is the Achilles heel of such a large biological unit as the cell. Cytologists studying the behaviour of cells after irradiation have made three observations of primary importance. They have found that living cells can be damaged with a very small dose while they are in the resting stage, that the injury thus induced is shown up during the successive cell division or mitosis, and that it leads to the breakdown of this vital process. We rightly look upon mitosis as a vital process; it is one of the greatest adaptations by which

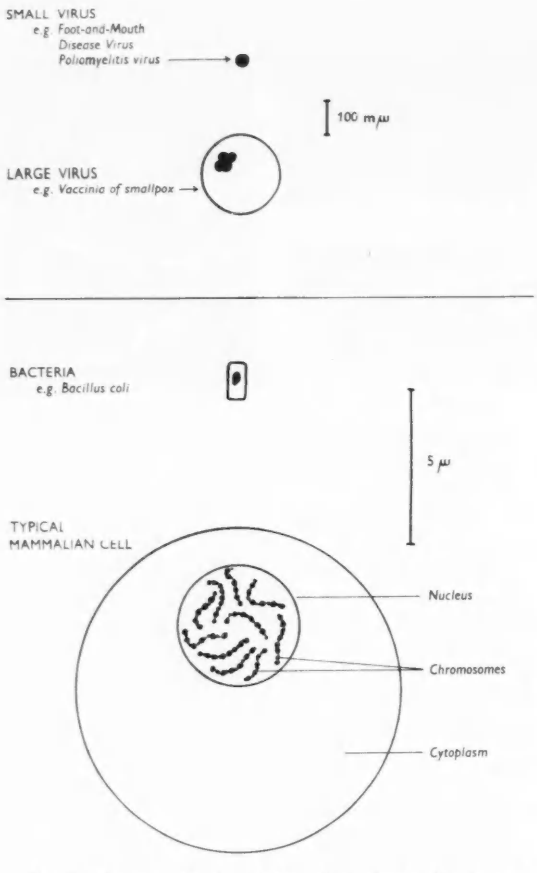



FIG. 4.—Diagram showing the 'sensitive volume' of various biological units. In the cell the genes borne on the chromosomes represent the most sensitive cell structures. The black areas indicate the sensitive regions of the various units.

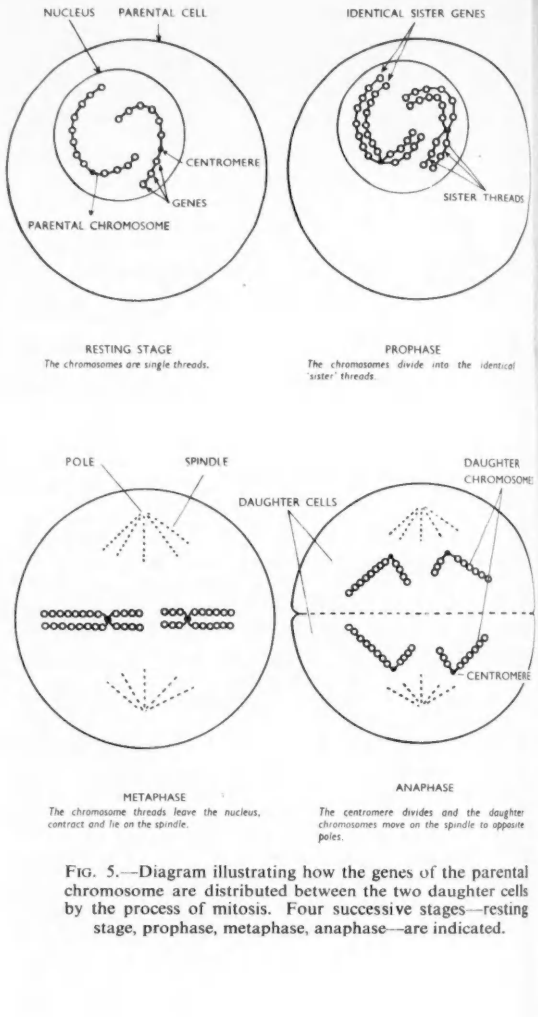



FIG. 5.—Diagram illustrating how the genes of the parental chromosome are distributed between the two daughter cells by the process of mitosis. Four successive stages—resting stage, prophase, metaphase, anaphase—are indicated.

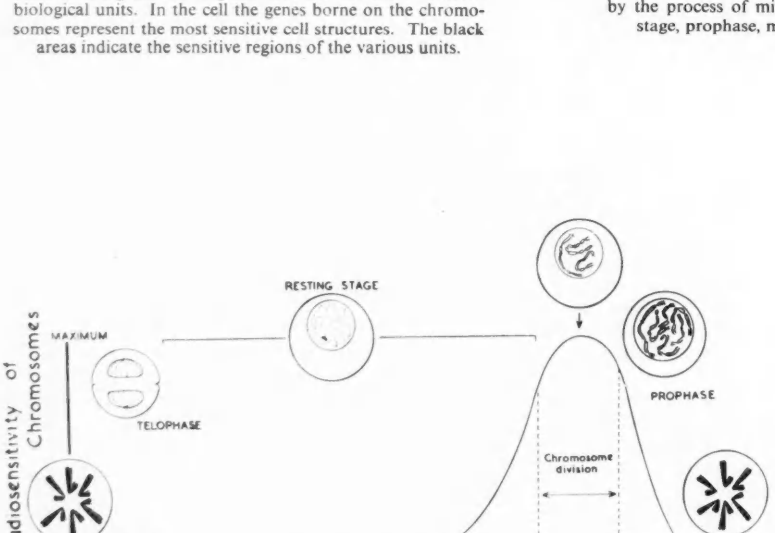


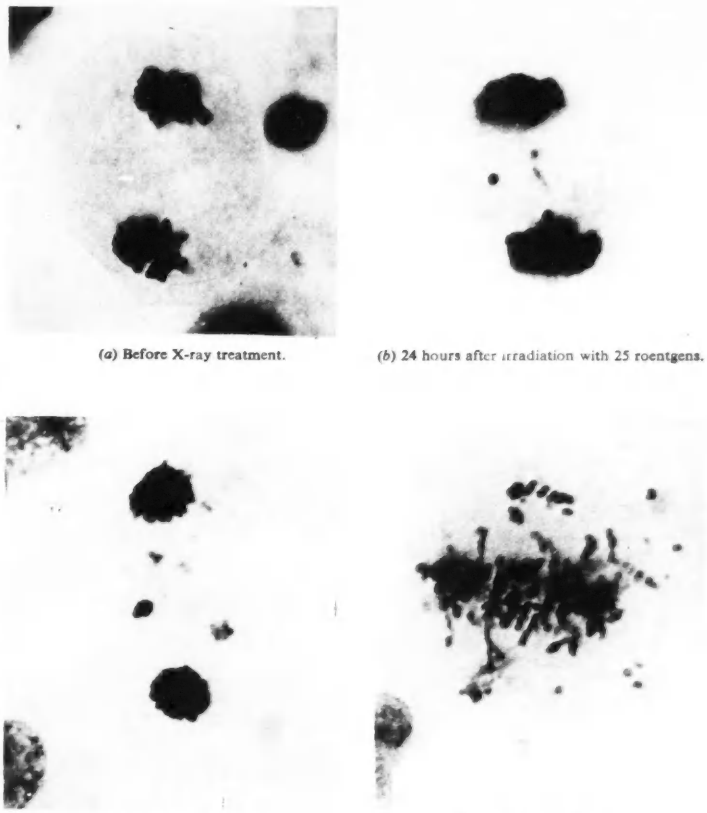

FIG. 6.—Diagram illustrating how the sensitivity of the chromosomes to radiation changes as the cell passes through different stages. It is seen that the maximum sensitivity coincides with early prophase during which the chromosomes undergo duplication.

Nature has solved the most complicated biological problem of securing equal distribution between two daughter cells of the hereditary material enclosed within the cell nucleus. (See Darlington, DISCOVERY, March 1945.) The hereditary units, known as *genes*, are carried in the chromosomes. They possess the capacity of self-reproduction, and are very similar in many respects to the viruses. The modern genetic concept assumes that the whole complex series of genes in a living cell forms a balanced biological system. Cases are known in which the elimination of even one single gene out of a set of 5000 present in each cell of the fruit-fly *Drosophila* can upset the normal activity of the cell to such an extent that it will die. The appearance of the whole organism, and the proper functioning of a single cell within it are both determined by the make-up of that system.

## Radiation Injury of the Chromosomes

Irradiation interferes with the stability of chromosome-structure. Ionisation breaks the chemical bonds linking the polypeptide chains upon which chromosome-structure depends, and the result is fragmentation of the chromosome thread itself. The broken-off segments are usually 'lost' in the cytoplasm during the first mitosis after irradiation; i.e. they are excluded from the daughter nuclei (Fig. 7). These fragments are loaded with genes, each of which is an important and necessary cog in the complex system of nuclear organisation; their loss prevents the normal functioning of the whole cell, though the nature of the disorder is still a mystery.

The amount of injury in the cell can be regulated by the dose of radiation; the higher it is, the greater is the number of broken chromosomes. But this direct relationship is valid only as long as one compares different doses of the *same* type of radiation. If we compare, on the other hand, equal doses of X-rays and neutron radiation, we find that the latter is more effective. Why should ionisation produced by neutrons be more effective in producing breaks than ionisations produced by X-rays? The reason lies again in the different ways in which ionisations are distributed. In X-rays, ionisations are distributed along the tracks of electrons in small clusters with wide spaces in between, while ionisations caused by neutron radiation are arranged densely along the tracks of protons. It is apparent that in order to injure the structural unity of the chromosome filament which is about 0·1μ thick, in the resting nucleus, not one but several ionisations are required within the chromosome threads. Physiological and chemical conditions in the cell can influence the sensitivity of chromosomes to radiation. This is the reason for the difference observed in the amount of injury shown by the chromosomes at different stages after the same dose (Fig. 6).



(*a*) Before X-ray treatment. (*b*) 24 hours after irradiation with 25 roentgens.

(*c*) After 300 roentgens. (*d*) After 2500 roentgens.

FIG. 7.—These photomicrographs (magnification × 1600) show the anaphase stage of mitosis in human cancer after various X-ray treatments. The amount of injury to the chromosomes increases with the radiation dose.

The analysis of the *initial* radiation effects is greatly complicated by events which follow them. It is a common occurrence that some of the broken chromosome filaments before they enter mitosis fuse again either in the old way, or in a new way, by reuniting with another broken thread. These abnormal reunions lead to the formation of chromosome bridges during anaphase which prevent the completion of mitosis. They must be considered as the secondary consequences of irradiation and can be used with caution in interpreting the initial radiation effects.

Cells can also be killed by breaking down or disorganising the closely integrated enzyme systems of the cytoplasm. Such an injury may be brought about when a sufficiently large number of ionisations occur within the cytoplasm. However, when we compare the doses necessary to destroy a cell by means of chromosome injuries and by enzyme inactivation, we find that a dose ten or one hundred times greater is needed for the latter purpose. We are, therefore, entitled to look upon the genes, and the string of genes or chromosome, as the real Achilles heel of the cell. Injury to the genes and chromosomes can

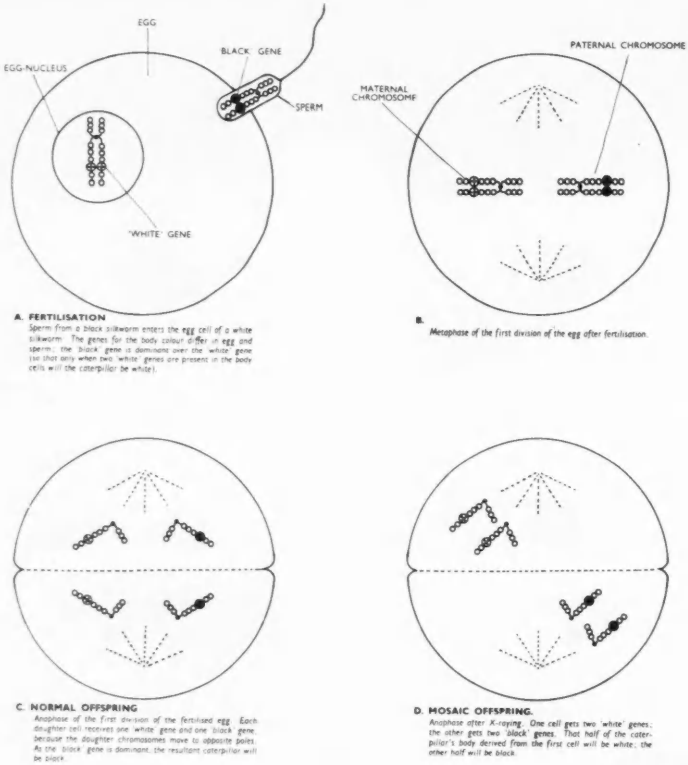

EGG
BLACK GENE
EGG-NUCLEUS
SPERM
'WHITE' GENE
A. FERTILISATION
Sperm from a black silkworm enters the egg cell of a white silkworm. The genes for the body colour differ in egg and sperm; the 'black' gene is dominant over the 'white' gene (so that only when two 'white' genes are present in the body cells will the caterpillar be white).
PATERNAL CHROMOSOME
MATERNAL CHROMOSOME
B.
Metaphase of the first division of the egg after fertilisation.
C. NORMAL OFFSPRING
Anaphase of the first division of the fertilised egg. Each daughter cell receives one 'white' gene and one 'black' gene, because the daughter chromosomes move to opposite poles. As the 'black' gene is dominant, the resultant caterpillar will be black.
D. MOSAIC OFFSPRING.
Anaphase after X-raying. One cell gets two 'white' genes; the other gets two 'black' genes. That half of the caterpillar's body derived from the first cell will be white; the other half will be black.

FIG. 8 (*left*).—Diagram illustrating how 'mosaic' areas are produced after X-rays, by interfering with the normal distribution of chromosomes. The gene responsible for black body colour is solid black; the gene for white carries a plus sign.

FIG. 9 (*below*).—(*a*) Silk-worm caterpillars; blacks are males, whites are females. (*b*) When the sperms of black males are X-rayed, many 'mosaic' caterpillars are produced showing black and white regions in their bodies (by permission of the Editor of *Radiology*).

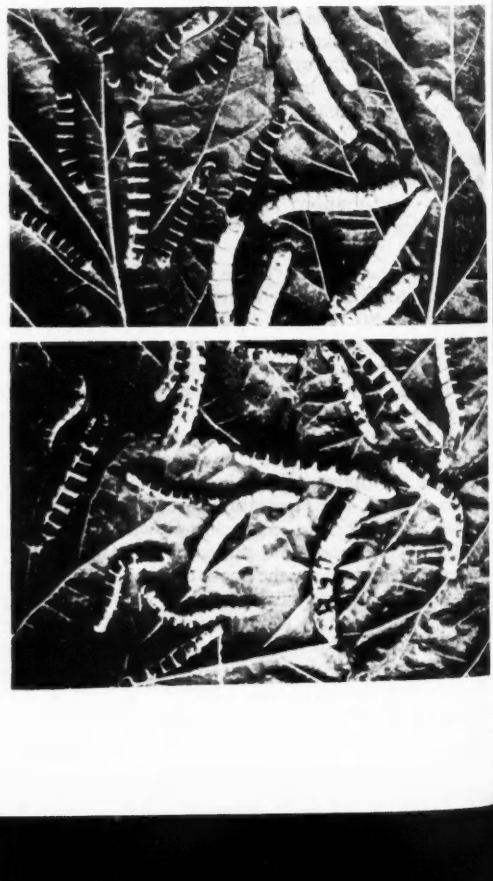
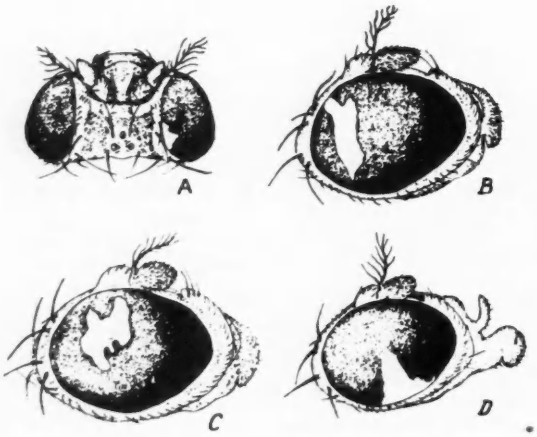


FIG. 10 (*below*).—Mosaic white areas in the red-pigmented eye of *Drosophila*. They were produced by exposing the larvae to X-rays (after Timofeeff-Ressovsky).



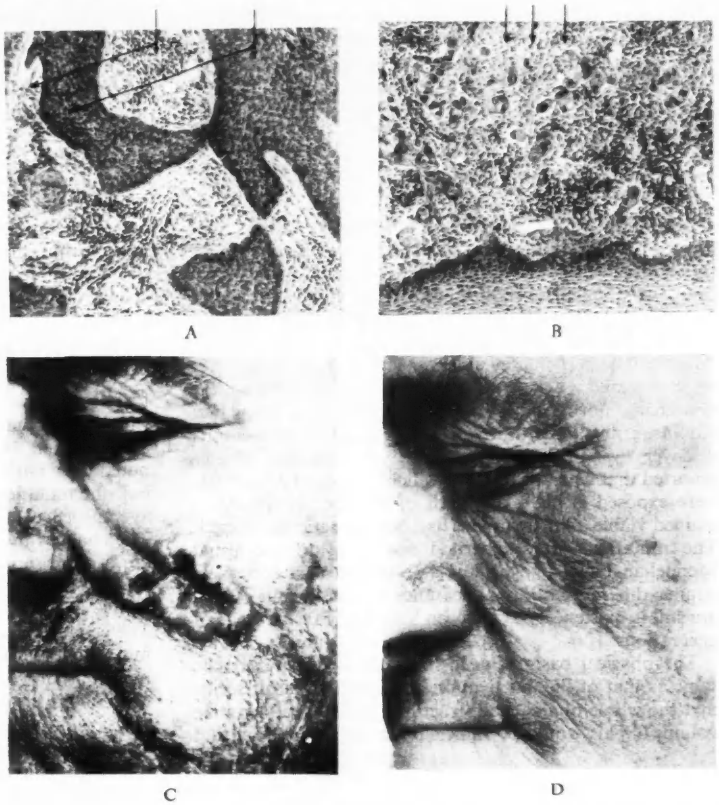



FIG. 11.

**The Treatment of Cancer by X-rays.**

(*a*) histological section showing the spreading or invasion of tumour into healthy tissue.

(*b*) the same after X-rays, showing how the tumour tissue is broken up and the tumour cells are dying.

(*c*) skin cancer before, and

(*d*) after X-ray treatment.

spell the destruction of the whole complex organisation of a cell.

## Pathological Effect of Radiation

If the radiation-produced injuries in the chromosomes show up only during the mitosis following exposure to radiation, one would expect that tissues in which the rate of division is high will suffer more than tissues in which cell division is rare, and this is found to be so. It is the reason for the rapid changes observed in the proportion of the various cell elements of the circulating blood, when the bone-marrow (the organ in which the red blood corpuscles are rapidly produced) is exposed to no more than a few hundred roentgens. The changes in the blood are followed by many other alarming symptoms; very often the person whose whole body is exposed, by accident, to 500–600 roentgens dies a few days later. We know now also that serious skin-lesions caused by radiation are brought about because the radiation destroyed the rapidly dividing cells in the deeper layer of the skin.

On the other hand the cell-destructive effect of radiation can be used to check the growth of cancer, a disease which is due to the cells in various tissues proliferating at a rate higher than that of normal cells (Fig. 11). The new sources of radiation raise our hopes that it will become possible to combat this scourge of mankind with greater efficiency than has hitherto been possible. Here the future seems especially encouraging for those deep-seated tumours (such as cancer of the lung) which have been difficult to attack by rays from the ordinary X-ray tube. The efficiency of external radiation has been greatly increased with the introduction of the betatron, synchrotron, cyclotron, etc. *Internal* radiation has also become feasible as a new method of treatment. This 'internal' treatment is carried out by introducing into the body radioactive substances such as radioactive phosphorus ($P^{32}$) or radioactive iodine ($I^{131}$), which then accumulate in particular tissues and organs. If these tissues and organs are cancerous, the concentration of the radioactive substance may bring about destruction of the tumour.

The changes induced by radiation are not always lethal to the cell. X-rays, besides breaking the chromosome filaments, may only induce, for instance, alterations in the distribution of the chromosomes without changing the numerical balance of the genes. The two daughter cells, on account of the irregular chromosome or gene distribution, will consequently differ from the parental cell in their genetic constitution. If the change takes place during embryonic development, many cells may be produced with the altered genetic content; this disturbance can often be detected because the adults will show morphological differences or 'mosaicism', with one part of the body different from the other (Fig. 10). An example of such mosaicism is produced by irradiation of the silk-worm. When females of a race with light-coloured caterpillars

were mated with irradiated males of a race with dark-coloured caterpillars the first-generation caterpillars, instead of all being dark-coloured according to the rules of Mendelism, had a number which were 'half-siders', one half of the body being like that of the father, the other half like that of the mother (Figs. 8 and 9).

## Gene Mutation

Ionising radiation can also induce changes in the molecular structure of the genes and yet leave them able to function and reproduce in the altered shape. This event is called *mutation*. The credit goes to Professor H. J. Muller for providing the experimental proof that radiation can alter the hereditary material and the changes thus produced can be perpetuated and transmitted to the offspring. He elaborated a very ingenious method of detecting these new changes or mutations in the descendants of irradiated parents, using the fruit-fly, *Drosophila*. The momentous discovery was made as early as 1929. In that year Muller reported that when the dose to which gonads of *Drosophila* were exposed is high, over half of the sperms which remained viable after treatment had been genetically altered. The mutations were inherited according to the usual Mendelian Laws, and he was able to establish quite new strains, different both in appearance and behaviour, which are still in existence, having been bred true for hundreds of generations.

The physical basis of gene mutation is apparently the same as that of the inactivation of a small virus. It seems that the whole of the gene structure represents a 'sensitive volume'. This would be sufficient reason for the fact that the number of mutations diminishes with equal doses of different radiations in the order: gamma, X-rays, neutron and alpha-particle radiations. Since Muller's discovery, a great deal of knowledge has been accumulated about the genetical effect of ionising radiation in plants and animals. There is no longer any doubt that gene mutations are produced by radiation in all living organisms, and breeding tests have shown that their frequency is high. Some of the X-ray induced mutations may prove to be of economic importance, e.g. mutations affecting the yield in cereals, but the great majority have been found to be deleterious to individuals and disadvantageous to the species (Figs. 13 and 14).

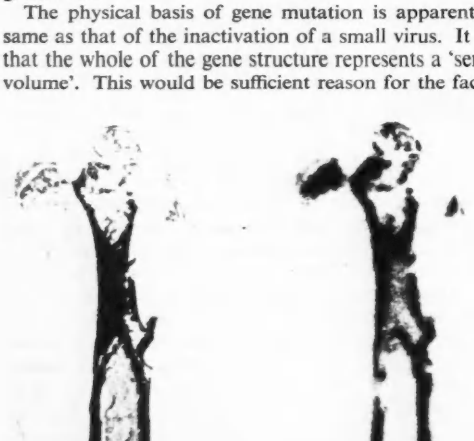


FIG. 12.—Photograph and auto-radiograph of longitudinal section of femur from rat, injected with radioactive strontium, showing the accumulation of the radioactive substance in the bone. The auto-radiograph (*right*) is made by placing and leaving the section on the photographic plate for several days. The blackening of plate reveals the presence of the radioactive material. (By permission of the Editor of *Radiology*.)

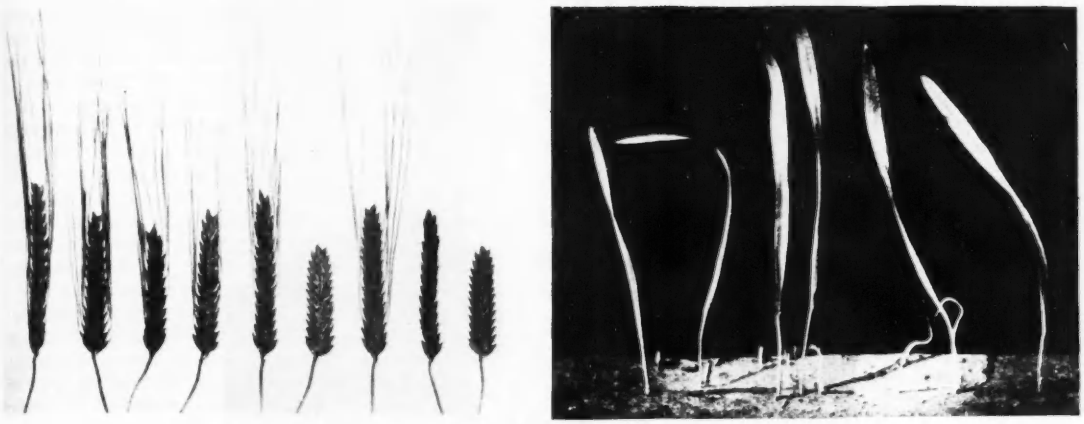
## Importance of Mutations

By closer scrutiny many of the mutant genes turned out to have a similar effect to that of the normal genes from which they sprang, but were less active in producing this effect. When the reduced efficiency of gene action is attributed to radiation, Muller found that after 4500 roentgens not one mutation was produced in 100 sperms but on the average *each* of the sperms carried 3–4 new mutations. The changes induced by radiation in the genetic material are a more serious matter than direct radiation injury to the body. The latter can be observed early on and protective measures can be devised to prevent its recurrence. The genetic changes can only be detected by close inbreeding, which is feasible in plants and maybe in animals, but not in Man. Before the mutation is detected it spreads throughout the population in a succession of many generations, and hundreds or thousands of persons will become carriers without being aware of it.

The human race already contains a great number of recessive hereditary defects, such as haemophilia, progressive muscular atrophy, retinitis pigmentosum, polydactyly, sterility, etc. 112 genes are known to be responsible for various skin diseases and nearly as many for eye diseases. Such inherited abnormalities are the result of 'natural' gene mutations, which have come about without irradiation. They had to spread far and wide in the human population through many generations in order to become manifest by the mating of two individuals both carrying the same hidden mutation. The chance that this may happen is very small indeed, yet such abnormalities as those mentioned above have become manifest and are today the source of great ills, personal as well as social. Irradiation increases the rate of mutation, and we know, for example, that a dose of 3000 roentgens of X-rays produce 12% mutation in *Drosophila*. This is about 100 times greater than the natural mutation rate. The magnitude of the mutation rate depends on the dose alone, regardless of how diluted and protracted or interrupted or concentrated in time the treatment may have been. This means that there is no threshold dose, and no matter how small a given dose there is always a chance, though it can be a very small one, that a mutation may occur.

## Protection

We have described the physical basis and nature of the various biological effects induced by ionising radiation. We have seen that injury in the living organism is of two kinds; one is *pathological*, the other *genetical*. The first



FIGS. 13, 14.—Mutations in barley (*left-hand picture*) and rye (*right-hand picture*) produced by X-rays. Normal ear of barley is on extreme left; some of the rye seedlings are deficient in chlorophyll. (By permission of Dr. A. Gustaffson Lund and Timofeeff-Ressovsky.)

type of injury shows itself in the person who was exposed, the latter effect concerns change in the hereditary material which will be manifest only in the descendants of the person who was exposed to the radiation.

Protection from the first kind of injury was a relatively easy task in the past, as compared with that facing us in the future. While a few millimetres of lead screen were found to be sufficient to capture the electrons of X-rays and radium, we need water-barriers three feet thick in addition to lead and concrete in order to 'decelerate' and capture fast neutrons from the cyclotron. In the past, three methods were in use to detect the amount of radiation received by man. The estimation was based on the blackening of photographic film, on the electric current in the ionisation chamber, and on changes in the proportion of the different cell elements in the circulating blood.

All these methods are inefficient when we consider the potential hazards associated with the use of radioactive isotopes. These elements such as radio-phosphorus, potassium, iodine, etc., are accumulated in different organs and tissues, thus they become the source of 'internal' radiation. They emit radiation for different lengths of time, perhaps for the rest of the subject's life. Our experiments with animals show that most of the radio-isotopes are deposited in the skeleton and stored near to the bone-marrow, the most vital organ for blood formation (Fig. 12). It is clear that in the case of radioactive isotopes absorbed in the body the physicists are faced with a formidable task, namely to estimate the distribution and the amount of radiation emitted by the radio-isotopes.

Yet we must know the rate of energy dissipation from these internal sources, because an excessive dose of radiation emitted from a minute quantity of radio-isotope for a long time can not only lead to tissue-lesions, but it can also produce cancer. In view of this serious possibility, the formerly accepted and widely used '*tolerance dose*' is replaced by a new and lower measure, defined as the maximum '*permissible dose*'. The carefully planned protective measures and the high efficiency of monitoring already in practice in the various Atomic Energy establishments show an appreciation of the great hazards involved in handling radioactive substances. The real difficulty is, however, how to control individual scientists, who are undertaking research in isolation. When radioactive substances are available almost on a commercial scale, they can become a serious menace to the human population, if not carefully handled. Radioactivity can be destroyed only by self-decay, hence the accumulation or dispersal of radioactive waste-products so long as they are radioactive remains a real danger to health.

Unfortunately the radioactive substances do not produce unpleasant sensations or painful symptoms when they come into contact with the investigator; there is nothing to warn him of the danger. Only clear understanding of the hazards can prevent accidents. In Sweden and Denmark all scientists and doctors who wish to handle radioactive substances have to undergo a very rigorous course of theoretical and practical training, and they are taught to treat these substances with the respect they deserve.

The genetical effects of ionising radiation need to be especially emphasised. We have explained the reason why the genetical consequences of radiation cannot be prevented; *they can only be mitigated by strict protective measures.* Gene mutations are almost always deleterious and on the evidence of experimental data we may predict that if they are produced with high frequencies they will, throughout the many future generations, kill more people whose germ-plasm is contaminated with the mutated genes than could be killed directly by the explosion of the atom bomb. It is our duty to safeguard the health of both the individual and the human race from the injurious effect of radiation in whatever form. At present it is for us to decide to what extent we are willing to control the use of radiant energy for the benefit of our *own* generation by cumbersome protective measures with a view to preventing the development of deleterious abnormalities that can be inherited in persons to be born 10–50 generations hence.

SIR ROBERT WATSON-WATT.

# Science, Politics and Citizenship

SIR ROBERT WATSON-WATT, F.R.S.

THE whole world is uneasy about the application of scientific knowledge. The politicians, and a majority of ordinary citizens, fear that these applications may go uncontrollably in the direction of further destruction of the bases of our civilisation. The scientific workers, and those citizens who have some direct contact with the mind of science, fear that controls and restraints may be continued and intensified to the delaying of applications which could easily and quickly raise the level of our civilisation far above any we have yet known.

Fears about the atomic bomb are allowed to obscure hopes for the beneficent utilisation of nuclear energy. Scientific workers are being diverted to organisational and improvisational activities in the mitigation of the world food crisis. That crisis would never have arisen had they been given in time encouragement and scope to apply the knowledge already in their possession. It is too late to use that knowledge in the present crisis; its use to avoid future crises will be further delayed by the claims on their time and attention which are made by the present crisis. Far more of the scientific workers than ever before have passed from the stage of dispassionate knowledge of scientific facts to passionate awareness of social needs; the immediate result is in some cases a reduction in the value of their unique long-term contributions in favour of non-unique short-term activities.

There is no greater necessity in the world of today than a closer understanding by the politician and the citizen of the motives and methods of science, and by the scientific worker of the inevitability of politics and the responsibilities of citizenship.

The basic scientific motive is a universal curiosity; an insistence on knowing the relations between one fact and another, one event and another; a demand for the painting of a vivid mental picture—whether in mathematical, mechanical, symbolic, or verbal colours—to permit the prediction, from past knowledge, of the consequences of hitherto untried combinations. The basic scientific reward is some elevation, however modest, of the whole stature of the human mind; a mind which for the scientific worker is a universal mind, nationless and ageless.

Inherent in this motivation and in this aim is an implicit or explicit faith in the perfectibility of the universal mind, with which is inseparably associated faith in the perfectibility of the individual mind. The scientific worker may not himself know that he holds this faith; yet his devotion to the extension of scientific knowledge would at best be meaningless and at worst be mischievous but for that faith.

Here is a fundamental contrast between the scientific worker and the extreme classicist. A relatively enlightened British Minister of Education has been heard to say, to an audience comprising many scientific workers, "Our education must essentially rest on the Classics, because they teach us how man has always behaved *and how he will always behave*." For the holder of such a creed it is not unnatural to believe that there are facts and knowledge that should be concealed, suppressed, or unexplored.

## Crimes against Science

To the holder of the scientific creed there are no bad facts, no evil knowledge. The crimes against science are the failure to establish the facts and the failure to publish broadcast the knowledge. Other crimes there may be in the applications of science, but those are crimes of the user and not crimes of the provider of knowledge.

Correspondingly, there can be no wrong direction of advance in science. There may be avenues of slow advance,

less satisfactory than those of greater speed. There may be sterile spurs and blind alleys, real or apparent. Some such alleys may be blind through the blindness of the explorer, and may open fruitfully after many years before a new explorer with new vision. But even a permanently sterile spur is a solid part of the whole tree of knowledge.

This is a doctrine which is held alike by the most fervent defender of the 'Freedom of Science' and by the most vigorous campaigner for the 'Planning of Science'. Where they diverge is below this lofty plane of quasi-religious devotion to increase of knowledge. It is at the level of selection of subject-matter for research that there enters, consciously or unconsciously, the factor of social awareness.

It is no discredit to either school of scientific worker that they differ fundamentally in their responses. One is prepared to work, patiently and on the whole humbly, adding a single fragment of carving to a cathedral of abstract science, limitless in its final extent and timeless in its calendar of advance towards completeness.

The other cannot look down dispassionately from the pure cold eminence of the eternal verities—no, not of the eternal verities but of successive and imperfect approximations to the eternal verities—on the immediate plight of those who, by the merest of accidents on any scientific scale of estimation, are his contemporaries and immediate followers on this minor planet of a minor sun.

Even the most abstract worker does not, in fact, find himself born with an inevitably foreordained line of activity in science. There is an infinity of scope for scientific advance; he can contribute to it along an infinite variety of routes grouped into a score of major categories. The social atmosphere of his time, the environment of his home, the personality of his teachers, will influence not merely his individual route but the category of route which he follows. He may be conscious or unconscious of the influence; it may be decisive or weak, but it is never absent.

Very rarely is the scientific worker moved by one and one only of the two legitimate driving forces of science, the desire to know and the desire to use. It is extreme to describe one as the motive of science, the other as the motive of engineering in its widest sense. But broadly the distinction is convenient if it is not overstrained. There are few physicists or chemists who are not to some degree 'engineers manqués', few biologists who are not potential physicians and surgeons. And there are few engineering or medical enterprises which do not make some contribution to that stock of 'pure' scientific knowledge from which they draw their inspiration and their technique.

## War and Peace

These are the ingredients of the scientific mind, the scientific motive and the scientific method which contribute to what is done in "the application of the forces of nature to the use and convenience of man". How are we to attain wisdom and constructive effect in such application?

The remarkably rapid advance in war-time of such scientific and technical devices as radar and the atomic bomb are frequently cited as among the 'miracles of science'. I believe that the release of energy from the atomic nucleus is in fact the very highest triumph that the human intellect has yet achieved. But the science and the scientific workers are the same in peace and in war. The peak intensity of effort, emotion, and enthusiasm in wresting a new secret from Nature is no less than in wresting victory from an enemy.

The difference between the relatively slow advance of nearly basic science and its applications in war and in peace is not inherent in the scientific world but in the political world which determines the facilities put at the disposal of the scientific world. It is fair to say of science and its applications, as of most other things, that humanity gets, on the whole, the world that it desires; it is nearly fair to say that it gets the world which it deserves.

Science does not claim to establish the whole of truth, save on a highly specialised and restricted definition of truth as "truth about the immediately measurable". Science is in itself part, but a part only, of the structure of "the whole truth", which includes the good, the noble, and the beautiful even when these are not quantitatively measurable.

I would ask whether, in fact, the release of the energy, or some little part of the energy, in the atomic nucleus has not been one of the major beneficent contributions of science to political science. For the very first time in the history of the world we have beyond doubt scared ourselves as ordinary citizens into wariness. We have it in our power to destroy ourselves and others with us. We have thought so, in a casual sort of fashion in the past, but now we do not merely know it—we are aware of it; and there is an enormous difference between knowledge and awareness. But the beneficence of that scaring process is not yet as far advanced as I would like to see it.

I do not know why we are discouraged from thinking as nervously, as horrifically, about other means of mass destruction as we are encouraged to think about some of the applications of nuclear energy. I am convinced that the atomic bomb as we see it now, and as we can visualise it in the middle future, is a poor weapon when compared with some of these perfectly terrifying methods of biological warfare of which some of us know by remote hearsay, but about which none of us appear to be sufficiently courageous to talk freely and in an enlightened way as we do about the atomic bomb. At least the atomic bomb has shaken the last relics of political complacency; it may even have opened our eyes to the fact that the atomic bomb alone is not the greatest menace to an unwise world.

It is a platitude to say that the safeguards on the application of science lie in the mind of man, but a platitude becomes a platitude because it is true; it merits no less attention because it is obviously true. The mind of the scientific worker and the mind of political man—that is, of every man—alike require modification, and the modification of minds is what we call education.

We require re-education; political man requires enhancements of his scientific consciousness; scientific man requires enhancements of his social conscience. Each is entitled to reject the claims and assertions of the other—but only if he understands them, not in detail, but in essence and broad content. The 'humanist' must know more of that branch of the humanities which is science; the 'scientist' must know more of the other aesthetic humanities, which are literature and its sister arts, and more of the factual humanities which are history. We cannot attain quick results; we have started late; we must begin by re-educating our educators, but we must begin.

Meanwhile we take comfort from the thought that just

as the black-versus-white distinction between 'pure' and 'applied' science is not found to exist in its extreme form in any save a minute minority of scientific minds, so is the black-versus-white distinction between 'scientific man' and 'political man'—and for the same reasons—a crude criterion of orienting value only in a world which is in fact painted in all shades of grey, enriched and enlivened by more vivid and more endearing colours.

The world of today, despite its present troubles, enjoys a far higher standard of material comfort and intellectual freedom than ever before. The scientific worker has been essential to the attainment of that standard; he has far more to offer. What we need is mutual understanding, and he seeks that understanding within the limits of two high principles which he cannot abandon. He knows no limit to the perfectibility of the human mind; he will work on no other assumption. He knows no limit to the value of measured truth; he will not believe that the suppression of measured truth can do material good to the suppressor which is not completely outweighed by the harm, moral and material, which such suppression inflicts on the suppressor.

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# Russian Contributions to Science

SCIENTISTS are not usually propagandists, and even when they are it is very rare indeed for their propaganda to take a personal turn. They have their quarrels, of course, and their rivalries, and naturally patriotism may colour their judgment occasionally. But you won't often find them trying to insist on their own uniqueness or to undervalue the work of others. They know that knowledge is international, the result of efforts by many people at different times in various parts of the world. Take Einstein, for example. Some of the foundations on which he built were laid by Euclid, a Greek; Galileo, an Italian; Newton, an Englishman; Maxwell, a Scot; Fizeau, a Frenchman; Minkowski, a Pole working in Switzerland; Lorentz, who was Dutch; and Michelson and Morley, Americans. Russia's great physicist, Peter Kapitza, put the point clearly in 1945. "But there is really no such thing as Soviet science," he said, "or British science: there is only one science . . ."

But that was in 1945. Today, things are different. Here is a typical Soviet outburst, a passage from *Questions of Philosophy*, published in Moscow a few months ago. Here it is:

> "The struggle for priority in capitalist countries merges into a struggle to ascribe as many scientific discoveries as possible to scholars of one's own nationality and race at the expense of all other nationalities and races. The more rapacious and piratical the imperialism of the given country, the more insolent and crude is the 'spiritual expansion' of its historians of science, who use the material of falsified history of science to try to show the 'superiority' (in the sense of greater scientific talent and fruitfulness) of their nation and the 'inferiority' (in the sense of supposed scientific backwardness and sterility) of other nations."

So in matters of science the capitalist nations are "rapacious and piratical"! What was Kapitza's experience?

His earliest work of note was done here in England at Cambridge University in a laboratory especially built for him and paid for by money from the well-known capitalist Ludwig Mond. And in 1934, when the Russian authorities detained Kapitza, then on holiday in his native land, Cambridge, so that he could continue his work, sent on the apparatus he had invented. In fact, two of his assistants were sent to help erect it. It was all quite amicable. And the money the Russian Government paid for Kapitza's installation was used by Cambridge University for the re-equipment of the Mond Laboratory.

So much for the implied charge of 'piracy'. Now for the second accusation—the statement that the capitalist nations falsify the history of science to prove their superiority. Well, there's nothing like a concrete example. So let's take a subject of great interest today, rocket flight and inter-planetary travel. In this field one of the most brilliant pioneers, especially on the theoretical side, was a Russian. Tsiolkovsky—this was his name—was born in 1857. In 1932, on his seventy-fifth birthday, he found himself sensationally honoured by the Soviet State—incidentally, much to his surprise. He was a genius, who, born the son of a forester, managed with negligible schooling and hardly any books to invent for himself, when he was only twenty-three, formulae connected with the velocity of light and the theory of gases. He built one of the world's first wind tunnels. His later work on rocket flight is now standard . . .

But how do I know all this? The answer is that I read it recently in a book written by Willy Ley, a German who has now become an American citizen. This doesn't sound as if the West disregards Russian science.

Now turn back to the past. Take, for example, the Russian, Mendeléef, acknowledged everywhere as the discoverer of the periodic table of the elements. There is in the whole world, I swear, no book on elementary chemistry or atomic theory that does not give this great Russian chemist his due. As for Britain, he was even honoured by the Royal Society of London by the award of the Davy Medal in 1882. Surely if Britain had been 'piratical' in those days she would have pressed the claims of Newlands, whose 'law of octaves' was an early but imperfect statement of Mendeléef's great principle. Now glance for a moment at an invention—the electric telegraph, the early history of which is very complex because of the great number of inventors at work simultaneously in several parts of the world. The best-known early history of telegraphy in the English language was written by J. J. Fahie in 1884. In it he states that the prototype of the well-known needle instrument was made by Baron Schilling, a Russian diplomat. Fahie goes so far as to say that Schilling's invention was (I quote his actual words)

"the immediate cause of the introduction of electric telegraphs into England".

But I need not labour the point. The accusations of the Moscow journalists just are not true. They are utter nonsense.

This hurling of charges of academic dishonesty by one nation at another is as unworthy as it is undignified. But having accused capitalist countries of faking history in their efforts to claim scientific superiority, Russian writers have recently committed precisely this sin—and on the grand scale. In fact, hardly a month passes without at least one disclosure of a Russian who, it is asserted, discovered or invented something before anyone else.

Some of the assertions, of course, are true. Schilling certainly invented the needle telegraph. Mendeléef devised the periodic table. Tsiolkovsky was the earliest of pioneers in serious rocket theory, and Professor Zhukovsky, in the early years of this century, worked out the mathematics of air-flow over an aerofoil. There is no reason why the Russians should not re-state these facts. No-one has ever denied them; they can be found in serious text-books in any language. But mixed with the just claims there are others less easy to accept. Mostly they have an element of truth, however twisted it has become for propaganda. For example, we are told that the lightning conductor was invented by Lomonosov in 1752, and that the same man conceived the law of conservation of matter and invented a model twin-propelled helicopter. And, as an afterthought, comes the statement that atomic energy and cosmic ray research are firmly based on Lomonosov's discoveries. I am quoting a claim made in *Pravda* in January last.

What is the truth? We know that Mikhail Vasil'evitch Lomonosov, who lived from 1711 to 1765 and was a professor at the University of St. Petersburg, was the first of Russia's great intellectuals and practically the founder of her literary language, being a poet of a high order. He has a complete entry to himself in the *Encyclopaedia Britannica*. Now it is true enough that in 1755 he published an account in Latin of his work on some electrical phenomena. In this there was a picture, which I have seen, of a suspended conductor wire used for experiments with lightning. A little research, however, reveals that many of the experiments were done in collaboration with the German-born Professor Richmann, who was killed by a lightning discharge in 1753 while actually experimenting. And in any case, Benjamin Franklin had in fact devised a lightning conductor as early as 1747, so it is reasonable to suppose that Richmann and Lomonosov were following up the work of Franklin and Musschenbroek, whose Latin book on physics was then available for all educated men. And what about cosmic rays and the atom? Well, in his treatise on electricity, Lomonosov, like Franklin, certainly discusses the Aurora Borealis. Is *this* the basis of the claim that cosmic-ray research stems from his work? As for the talk about Lomonosov's model helicopter, such toys were plentiful in the eighteenth and nineteenth centuries. We need not take this seriously.

Another Soviet assertion, though, has rather more weight. It is that the first man ever to communicate by radio was the Russian A. S. Popov. He was an early and ingenious experimenter and certainly succeeded in 1895 in communicating by waves between transmitter and receiver. We know this because his account was published in 1896 both in Russia and England, and Sir Oliver Lodge wrote an appreciation of his work in 1900. But if we are to pursue the trivial business of tracking down hourly or daily priority, then we discover that Lodge himself communicated by Morse code across a few hundred yards of open air at the annual meeting of the British Association at Oxford in the late summer of 1894. If, then, we take as a criterion of priority the first communication of a radio signal, Oliver Lodge has it. But for the actual discovery that electromagnetic waves travel in space, the credit must go to Heinrich Hertz, the German Jew who demonstrated this in 1888.

So far, the doubtful claims we have dealt with have had at least some basis of truth. But what can be said of the astounding assertion that penicillin was produced in Russia in 1868? Or of the pronouncement that the steam engine was invented by Shapkovsky and by Polzunov? And then there's Mozhaisky, to whom is now attributed the building of an aeroplane in 1882. It is said that he also invented ailerons, and made a load-bearing kite. Well, perhaps he did. All that the historian of science can say is that as recently as 1938, Mozhaisky was not sufficiently known to get even an entry in the *Great Soviet Encyclopaedia*. The Russians can hardly in these circumstances blame the rest of us for being unaware of him.

Well, Mozhaisky is a mystery. We must await further evidence. Meanwhile, in one instance at least, it is clear that the Russian nationalists have over-reached themselves, for they attribute the first electromagnetic motor to Jacobi of St. Petersburg. The truth is that after Michael Faraday's demonstration of the motor effect in 1821, many men tried to produce practical machines. One was Davenport in America. Another was Jacobi. Both succeeded in 1834, and it looks as if Jacobi has the priority by three or four weeks, a fact admitted a few months ago in the American periodical *Electrical Engineering*, where the writer called him 'de' Jacobi. So far so good. But Moritz Hermann von Jacobi was, in fact, not a Russian at all, but a German, born at Potsdam. It was not until 1837, three years after his invention, that his renown procured him an invitation to work in Russia.

But what is the use of detailed controversy? In fact, it comes to this. Russia, a great and talented nation, has had her share of great men; just how big a share is not worth arguing. In such widely separate fields as music and chess, for instance, Russians have proved pre-eminent; in science hardly less. It may well be that in the last century, when science and invention made such enormous strides, Russian genius lacked the support of technical resources, so that ideas did not readily reach practical conclusion. It might even be argued that some Russian work of a high order has, for this reason, lacked full recognition. The same is true of a thousand unacclaimed geniuses in every country. As for "rapacious piracy" on the part of Russia's neighbours, to this charge the text-books of the West are an immediate and conclusive answer. We can leave it at that. The abusive statements and extravagant claims that Soviet writers, politically inspired, are now making, will harm only Russia. If her research students start to believe that they are intellectually a master race, needing no aid from others, then it is *their* work, not ours, that will suffer.

*(This article is the substance of a B.B.C. broadcast in European and Overseas Programmes.)*

# ANIMALS on the ROCKS

**This new set of photographs by Dr. Douglas P. Wilson, will enable readers who are holidaying at resorts where the coast is rocky to identify many of the seashore animals they find. Dr. Wilson is Britain's best-known photographer of marine animals and author of the picture book "They live in the Sea".**

Grey Top Shells (*Gibbula cineraria*) × 1½.
Common below half-tide level and in rock pools. Grey markings on shell.

Painted Top Shells (*Calliostoma zizyphinum*) × 2.
Sometimes common on the lower shore levels. Often with bright variegated coloured shells.

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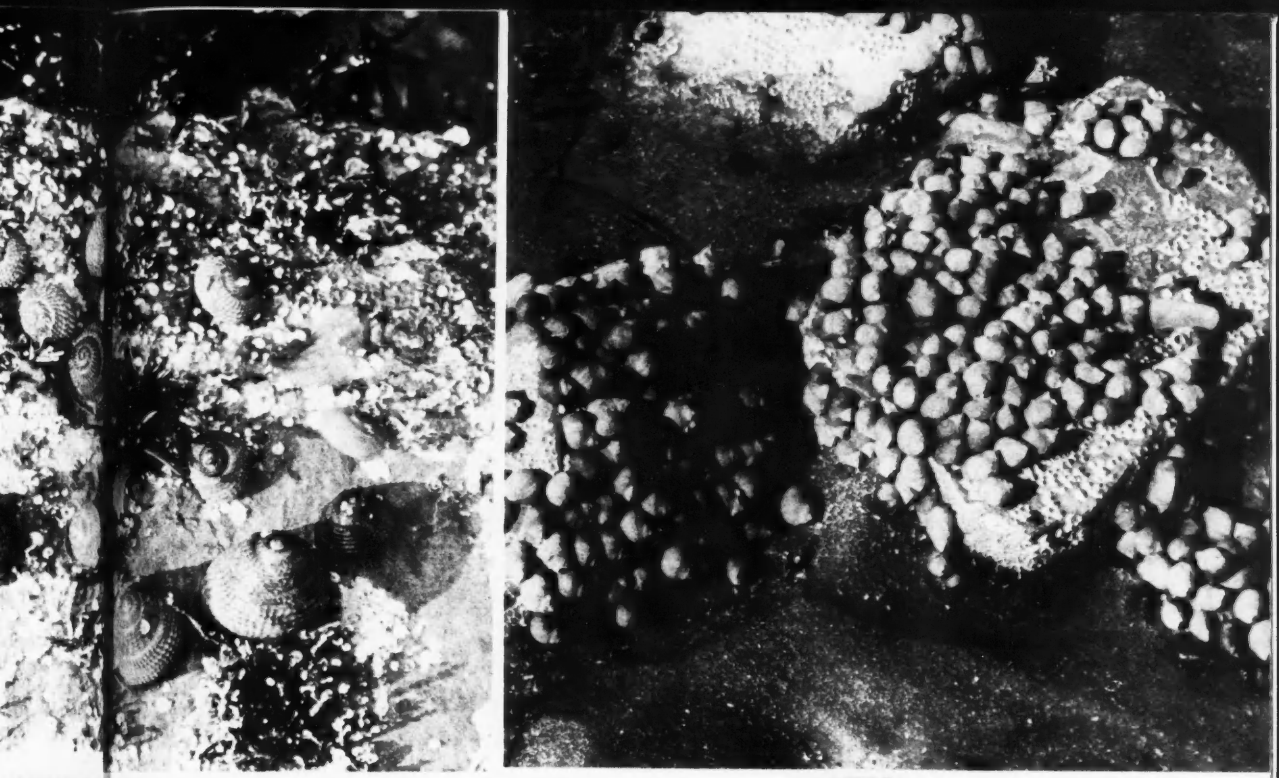
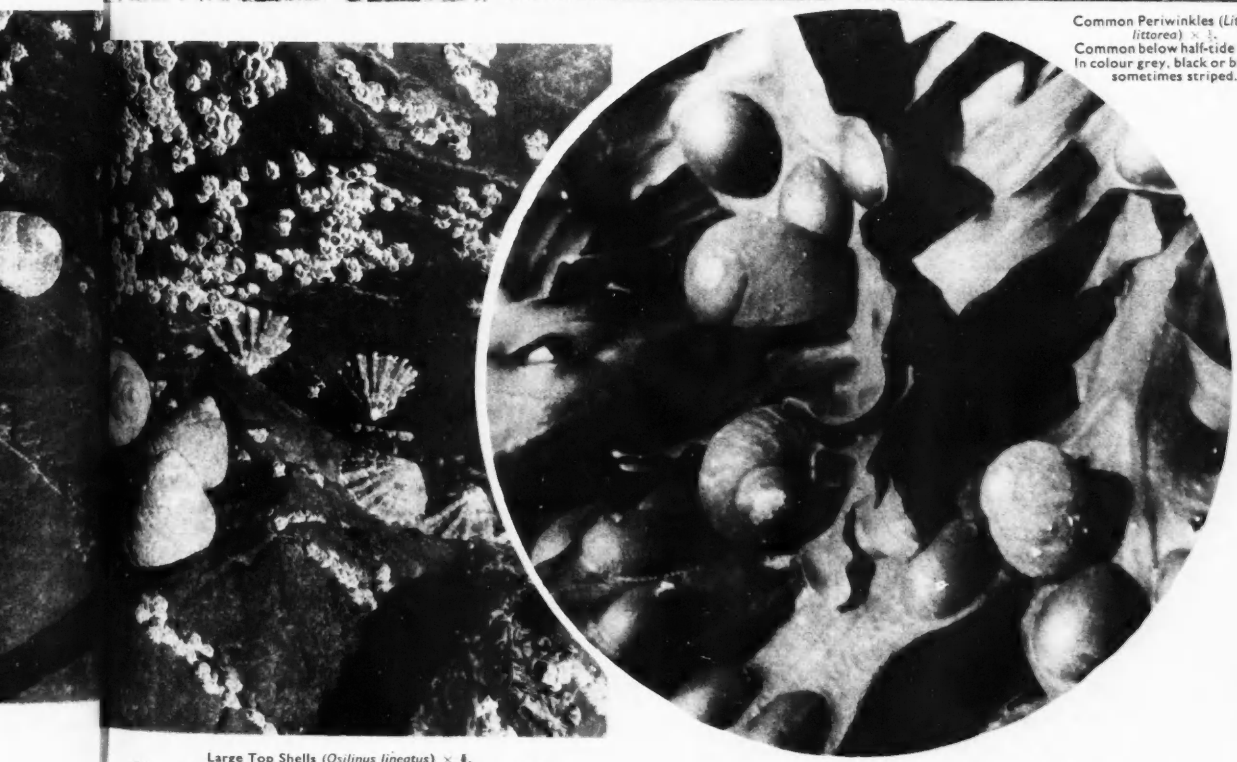


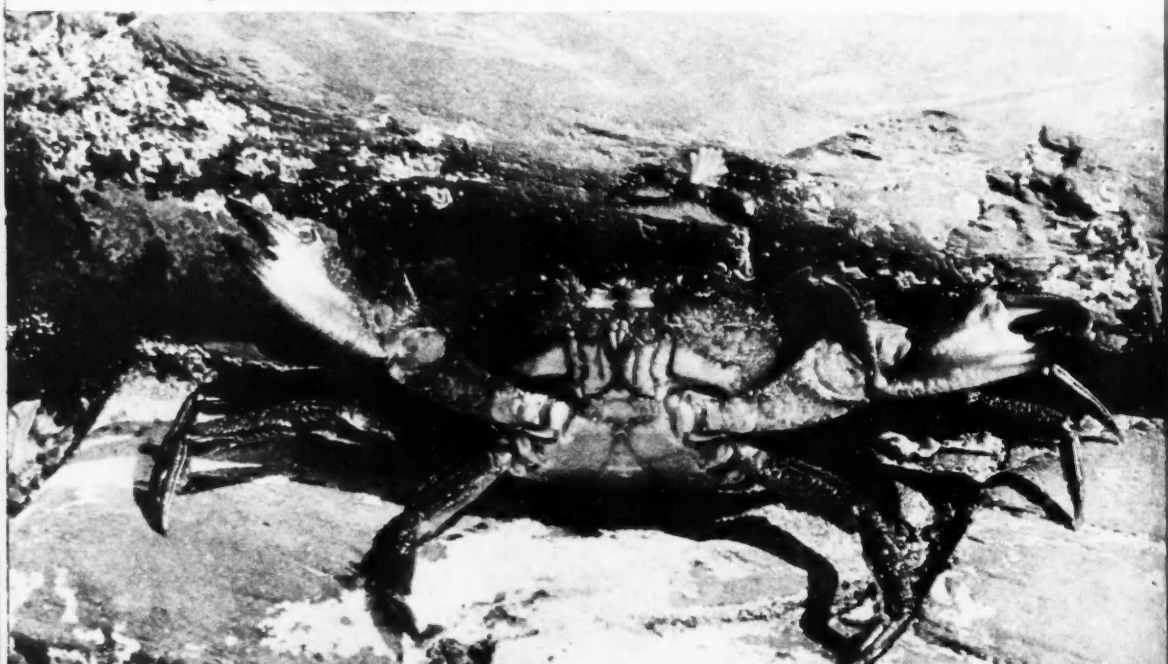
Common Periwinkles (*Littorina littorea*) × ⅔.
Common below half-tide mark. In colour grey, black or brown, sometimes striped.



Large Top Shells (*Osilinus lineatus*) × ⅔.
Often common on bare rock about half tide level. Grey in colour. Also visible are limpets and acorn barnacles.

Smooth Periwinkle (*Littorina obtusata*) 2.
Common in the mid-tidal levels on seaweeds. Shell with flattened spire, often bright yellow in colour, or brown, black or greenish.

Young Edible Crab (*Cancer pagurus*) × ⅔.
Brownish with a crinkled margin to the carapace. Bundles up its claws and legs when turned over on its back.



Velvet Fiddler Crab (*Portunus puber*) in defensive attitude × ⅔.
The most pugnacious shore crab, very common on southern and western shores. It has red eyes, bright blue joints and purple and brown markings.

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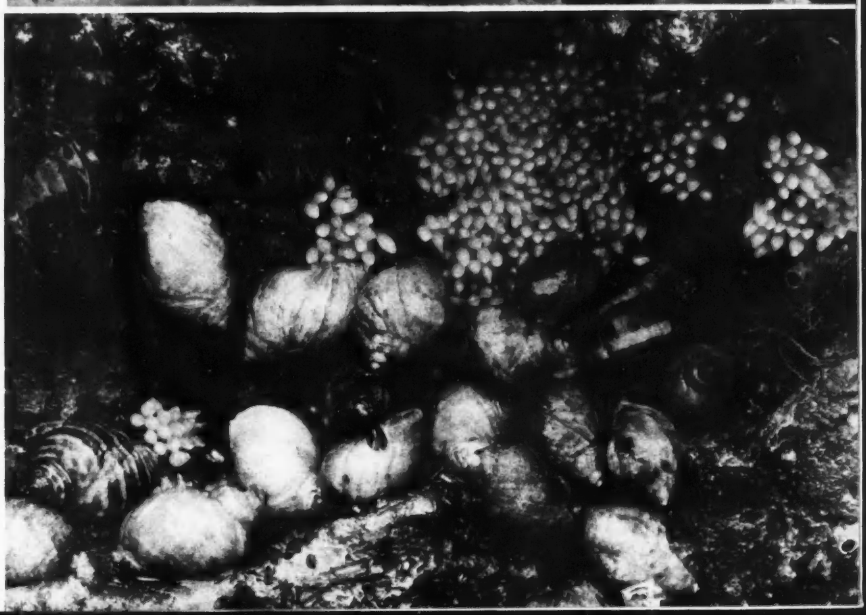
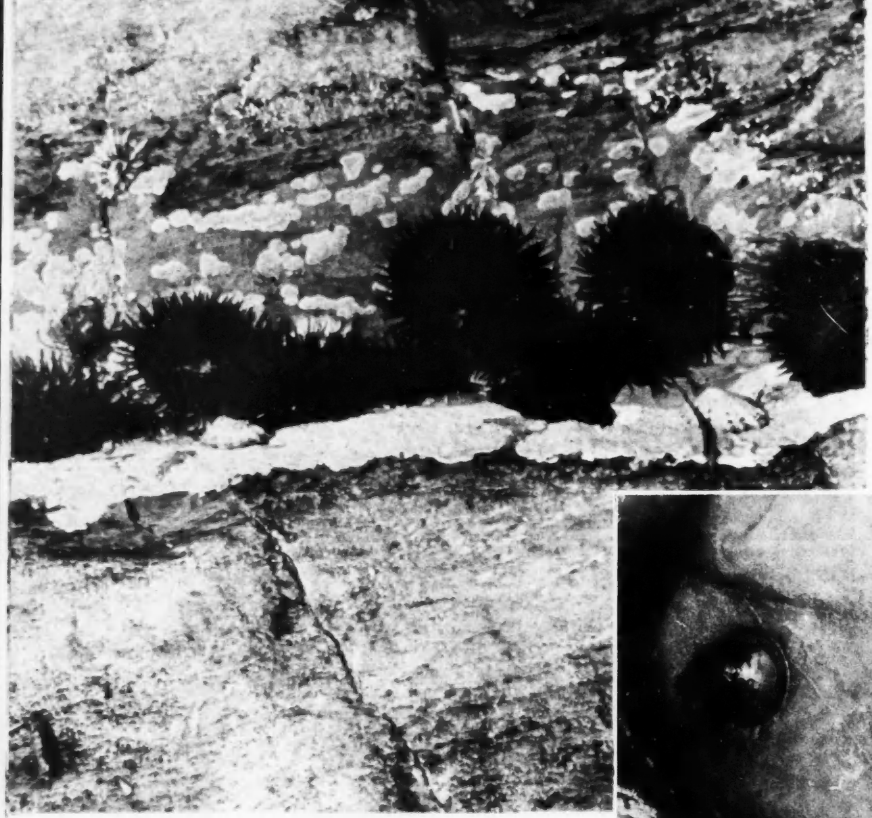
Dog Whelks (*Nucella lapillus*) × ⅔.
Very common on all rocky shores. Carnivorous. Shell very variable, colour depending to some extent on food eaten. The commonest variety, white or dirty yellow or grey, is generally feeding on acorn barnacles as in this picture where most of the barnacles have already been eaten.

Dog Whelk (*Nucella lapillus*) eating a mussel × 1¼.
When mussels are eaten the shell is sometimes brightly coloured and banded mauve, brown or black. In eating a mussel a hole is bored through the shell to admit the proboscis. A partially bored and abandoned hole in a thick part of the mussel shell is clearly visible.



Dog Whelks (*Nucella lapillus*) depositing egg-capsules × 1.
The yellow, sometimes purplish egg-capsules of the dog whelk are frequently to be seen in shady rock crevices and on the undersides of large stones. In this picture striped mussel-eating varieties of the dog whelk are seen.



Beadlet Anemones (*Actinia equina*) closed up at low tide × ½.
Generally dark red, sometimes brown or green, often abundant, looking like small rounded jellies on the rocks.

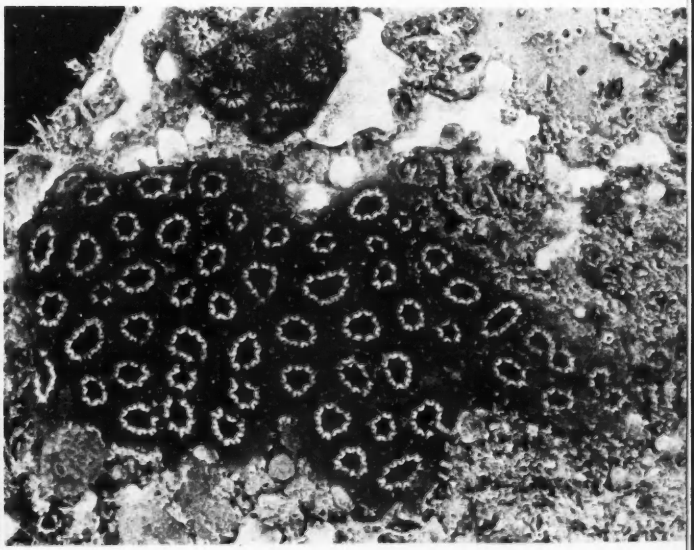
Beadlet Anemones (*Actinia equina*) expanded in a rock pool × ½.
A group of these flower-like animals ready to capture any small animal that should happen to brush against their stinging tentacles.

Acorn Barnacles (*Balanus balanoides*) × ½.
This is the commonest species on most shores.

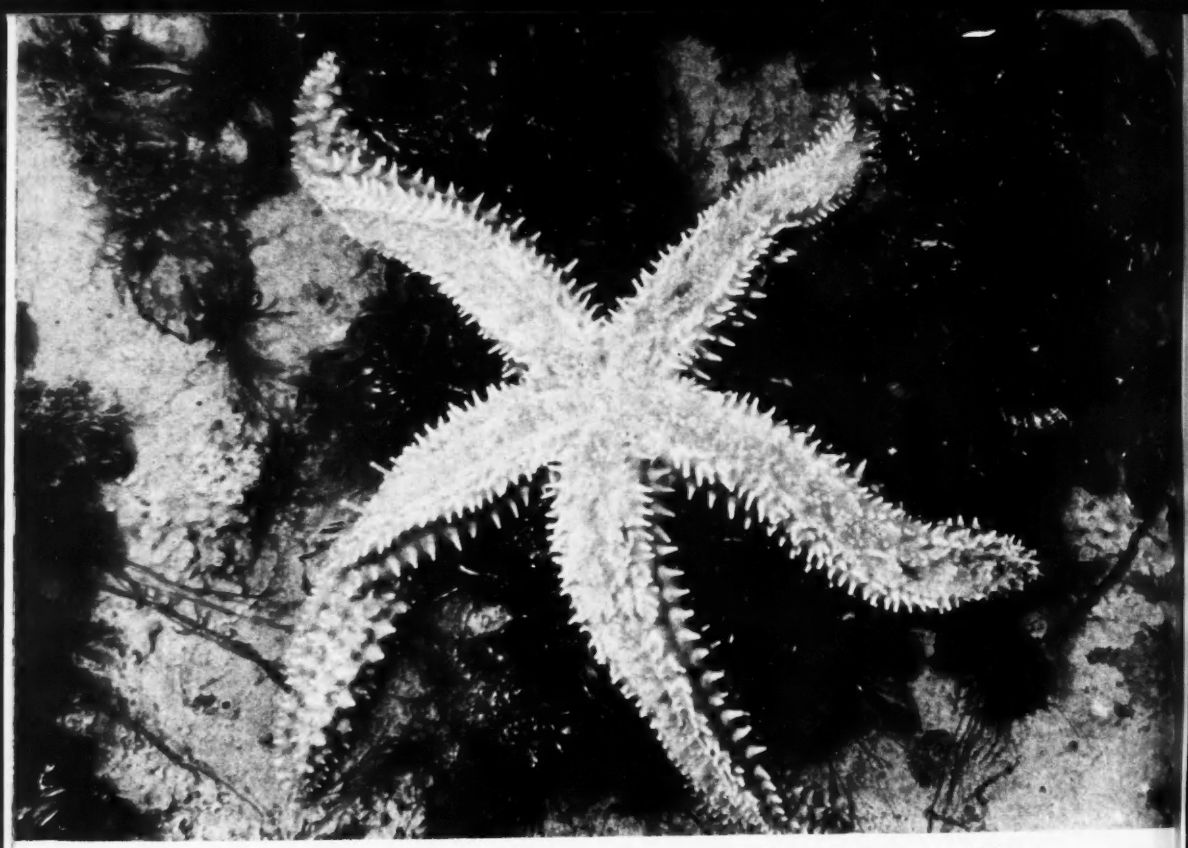
Group of Opelet Anemones (*Anemonia sulcata*) lining a crack in a rock pool. × ½.
This beautiful species is abundant in the rock pools of Devon and Cornwall and other westerly shores, but is rare or absent north and east. Tentacles bright green in colour, or brown and rarely retracted.

Breadcrumb Sponge (*Halichondria panicea*) × 1.
Very common on the lower levels on rock shielded from the sun. Yellow or greenish yellow in colour.

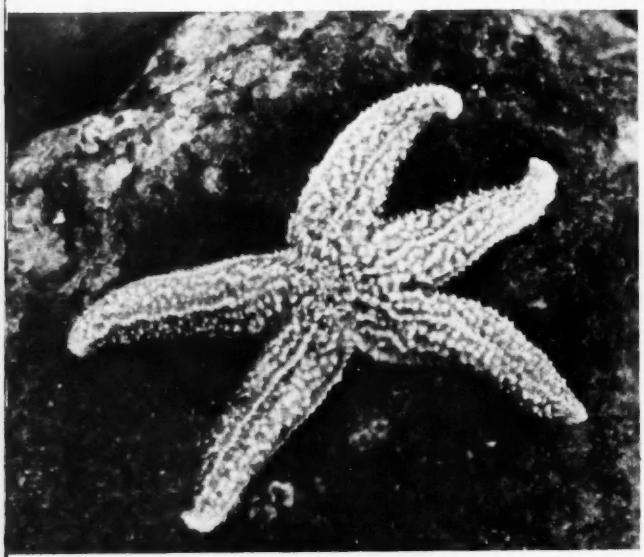
Shanny (*Blennius pholis*) guarding eggs × ½.
A flat roofing stone has been removed to reveal the fish and the eggs underneath. A common sight on most shores in the summer.



Golden Stars Tunicate (*Botryllus schlosseri*) × 1.
Common on underside of shore stones on the lower levels and in pools. Often brightly coloured.

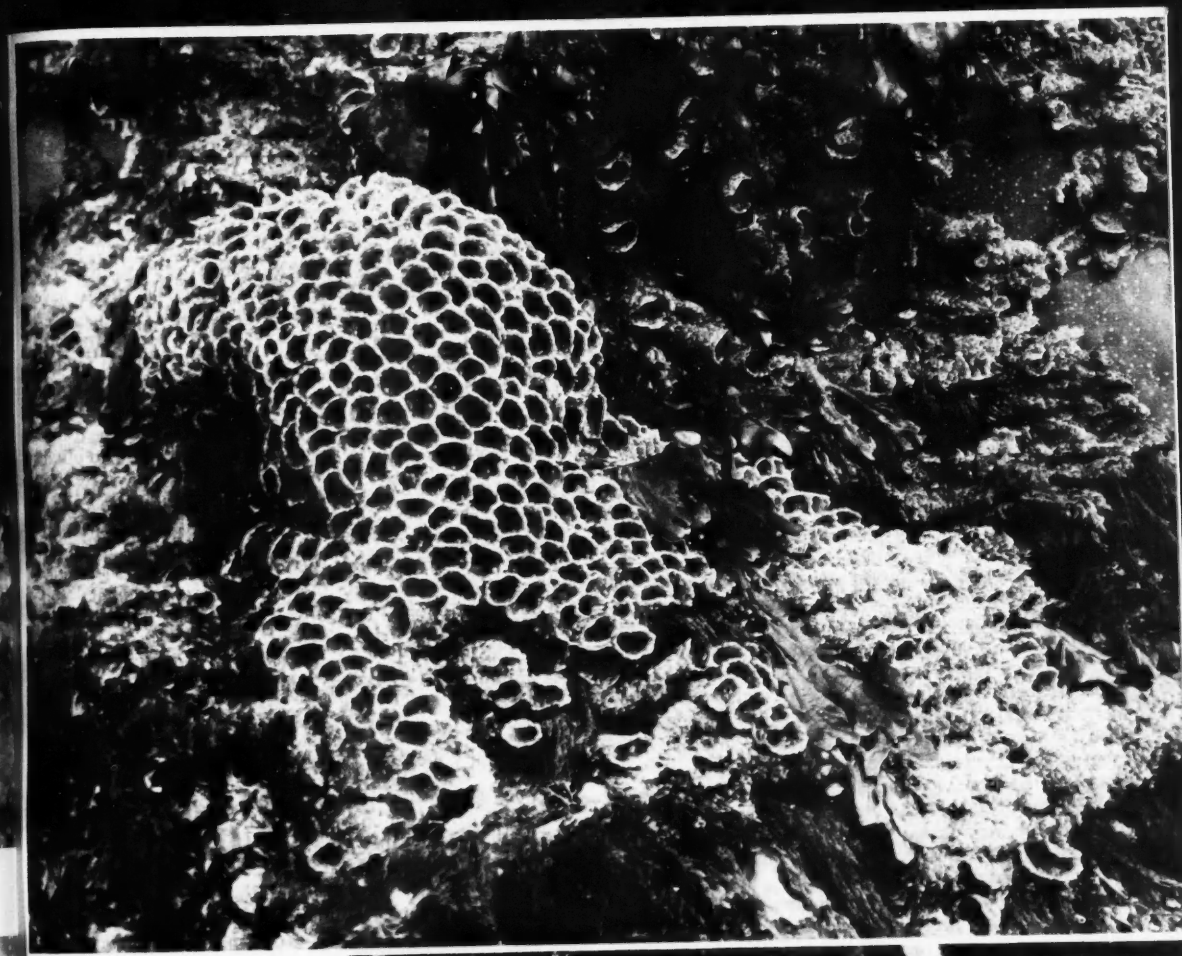


Spiny Starfish (*Morthasterias glacialis*) × ½.
Yellowish grey, bluish or greenish grey in colour. Common in south-west on lowest shore levels. This specimen is turned over to show the tube-feet.



Common Starfish (*Asterias rubens*) × ⅔.
Reddish brown or yellow. Young specimens sometimes very common on the lower shore levels. Feeds on mussels, etc.

Purple-tipped Sea-urchin (*Psammechinus miliaris*) × ⅔.
Greenish with purple tips to spines. Generally on undersides of stones or in rock crevices on the lower levels. Usually covers itself with pieces of seaweed, shells, etc.



The Honeycomb-Worm (*Sabellaria alveolata*) builds masses of sandy tubes, sometimes several feet across, on moderately wave-washed rocky shores where there is a plentiful supply of clean sand × ⅔.

Tubes of the Keeled Tube-Worm (*Pomatoceros triqueter*) × 1½.
The tube is of lime and very hard. When submerged the worm exposes a crown of feathery filaments at the entrance; at low tide it retreats within and corks up the entrance with a stopper.

# Nitrogen, the Element of Life

D. P. HOPKINS, B.Sc., F.R.I.C.

If the elements of plant and animal nutrition had to be placed in order of importance, nitrogen would surely be placed at the top of the list. For plants it is the principal growth-influencing nutrient; though carbon, hydrogen, and oxygen may be larger structural components of plants, the size and the rate of growth of a plant is directly determined by the nitrogen available in the soil. In animal nutrition we know that protein is both life itself and the stuff of life, but it is nitrogen which is the 'stuff' of proteins and their constituent amino-acids. Among the organic molecules the outstanding characteristic of the proteins is their consistent content of nitrogen; indeed, it is a standard method of calculating amounts of protein in feeding-stuffs to multiply their nitrogen content by a general and fixed factor.

It must be one of Nature's supreme parodoxes that nitrogen in simple, elemental form comprises 80% of the world's atmosphere; "Water, water everywhere, Nor any drop to drink" might well have been said of nitrogen, for upon each acre of world surface 150,000 tons of the element press down but merely behave as the almost completely inert diluent for oxygen, carbon dioxide, and moisture. Man's greatest triumph over the hard facts of his environment is not the atomic fission of World War II; it is the synthetic and large-scale industrial fixation of atmospheric nitrogen finally achieved in World War I. Before this discovery we were indeed 'plundering the planet' for combined nitrogen. Now we can have just as much as we decide. The raw material source—the air—is as inexhaustible as infinity. The tonnage of nitrogen compounds produced is a simple function of the effort given to constructing fixation factories and keeping them in operation.

After twenty years of general introduction the fixation processes were providing 75% of the world's nitrogenous fertilisers, and at first analysis this sounds like a success-story. But the true criterion is not the extent to which fixation is employed in making some specific annual tonnage. When production possibilities are unlimited it must be asked whether consumption has risen to the most desirable figure. In this sense the truth is disappointing. World farming as a whole still makes an almost inappreciable use of nitrogenous fertilisers. Even in modern agricultural systems the regular applications that are made are substantially below those recommended by research. Sir Henry Tizard observed two years ago that a more energetic utilisation of past research results was of greater practical importance than new research; the use of nitrogenous fertilisers is an outstanding example of this general comment. The Dutch farmers, and perhaps also the Belgians, are a lone minority who have learnt how to make the most effective use of this century's greatest scientific opportunity. Is it a coincidence that Dutch yields per acre are the highest in the world, that Dutch grassland can support twice as many cattle as ours per acre and that their cows produce about 50% more milk per lactation? The world must make a wider use of synthetic fixation in future or Malthusian storm-clouds will inevitably gather over the populations of the crowded countries.

We cannot rely upon the so-called 'nitrogen cycle'. To some extent this conception has been misleading. The positive contributions of the nitrogen-fixing organisms have received too much of the limelight while too little has been directed towards the negative activities of the nitrate-reducing organisms. It is, after all, a cycle. And if favourable bacteria can feed upon the inert nitrogen of the air and convert it into combined nitrogen, unfavourable bacteria are no less able to revert combined nitrogen into the gaseous element. Nitrogen is also readily washed out of soils, especially soils which have been bared after an autumn harvest; the nitrate form, once reached, is either assimilated by growing plants or rainfall sweeps it away into drains, ditches and rivers. Furthermore, man has imposed a serious leak upon the cycle by the widespread introduction of the water-closet. Hygienic and inoffensive though this civilised gadget may be, it ensures that almost all man's waste nitrogen is lost; for the nitrogen in sewage is mainly soluble and in water sanitation it becomes so diluted that recovery is impracticable.

The nitrogen cycle is not a liberal equilibrium within which crops can manage to secure enough of this nutrient. 'Enough' is a relative term. It depends upon the number of people in the world requiring food, upon the standard of diet they expect, upon the amount of cropping that must take place to provide that food, and upon the acreage of soil that is available. If extra supplies of combined nitrogen produce bigger crop yields, it must be assumed that the previously accepted standard of nitrogen supply was inadequate. It is true that from a certain point crop responses to extra applications will begin to fall off; what is called the law of diminishing returns must operate. Also, it must never be forgotten that the supply of other essential plant-foods will sooner or later introduce a limiting factor that brings the responses to nitrogen to a standstill. Nevertheless, there is ample evidence—indeed, a great mass of evidence—in research records proving that we do not yet apply nearly enough nitrogen to our major crops. A good deal of this evidence is by no means new but has been available for years.

During the recent war Dr. G. A. Cowie made a survey of one-year farm tests carried out in this country between 1896 and 1940 to measure the response of wheat to fertiliser treatments. Over 200 such tests were brought into the survey. The criterion of efficiency was the obtaining of an increase in yield of greater economic value than the cost of the fertiliser application—what agricultural scientists call an economic response. Where 1 cwt. of sulphate of ammonia (or its equivalent for nitrogen value when other fertilisers were used) was applied per acre, an economic response was given in 79% of the tests. But where 2 cwts. of this nitrogenous fertiliser were applied, there was an economic response in 87% of the tests. The average British dressing is between ½ and ¾ cwt. per acre, and Cowie estimated that a general rise to the 2-cwt. per acre standard would "produce on 2 million acres over 200,000 tons more grain and 500,000 tons more straw. Here is a method

whereby with little extra labour on the farm a vital addition to our food supply could be obtained."

## Protein Output Doubled

Yet this story of nitrogen and wheat is almost trifling when compared with the story of nitrogen and grass. Fertiliser nitrogen not merely produces more grass; it profoundly influences its nutritional value and produces grass with a much higher protein content. In general the effect of fertilisers upon nutritional values of crops seems quite small; the relationship of grass and nitrogen is a striking exception. Twenty years ago field tests at an English research station showed that moderate nitrogen applications could raise grass yields by 75% *but at the same time* raise the protein output by 100%; numerous American tests have given similar results since. Post-war investigations at the Hannah Dairy Research Institute in Scotland have shown almost incredible gains in protein output per acre as a result of heavy nitrogen fertilisation. Applications greatly exceeded those which are usual in any system of farming, even that of the best Dutch farms. In some experiments as much as 18 cwts. of 'Nitro-Chalk' were applied per acre; in these the yield of grass (from pasture-land) was not quite doubled but the protein output per acre was raised by more than 250%. One sentence from the First Report of the Committee on Industrial Productivity, published this spring, seems worth quoting here: "Today less than a quarter of the 18 million acres of grassland in the U.K. receives dressings of nitrogenous fertiliser in contrast with the very much higher proportions for cereals and root crops—in spite of the fact that experimental work has shown that the response to a given quantity of nitrogen is greater in the case of grass than for cereals or root crops."

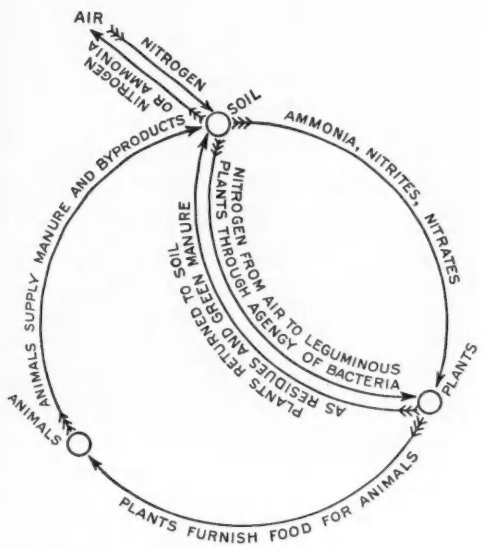



FIG. 1.—The Nitrogen Cycle (from "Soils and Men", U.S. Dept. of Agriculture Yearbook of Agriculture, 1938).

As already reported in DISCOVERY (May, 1949, p. 164) the most urgent recommendation made by this high-level committee was for a substantial increase in British production capacity for nitrogenous fertilisers.

It is still broadly true that nitrogen must be in the simple nitrate form to be readily assimilated by plants. But combined nitrogen is acquired by soils, or added to them, in a wide range of chemical forms. The more complex the nitrogen molecule, the longer the series of breaking-down processes which have to take place in the soil; these are achieved mainly by soil micro-organisms, though some stages are purely chemical changes brought about by soil reactions. Nitrification, which is the natural conversion of other kinds of nitrogenous material into nitrates, will occur in any soil that is fertile. The final stages in the chain of conversions: ammonia→nitrite→nitrate are achieved remarkably quickly by soil bacteria in warm weather.

We have a fairly wide range of choice for the forms of combined nitrogen that we add to soils, and in synthetic fixation we also have some range of choice for the form of combined nitrogen that is produced. For example, there are ammonia, sulphate of ammonia, ammonium nitrate, ammonium phosphate, urea, urea polymers (see below), calcium cyanamide, and the proprietary fertiliser 'Nitro-Chalk'. If rates of nitrogen application are increased, careful consideration must be given to the form or forms which are mainly used. This is not a minor matter of detail.

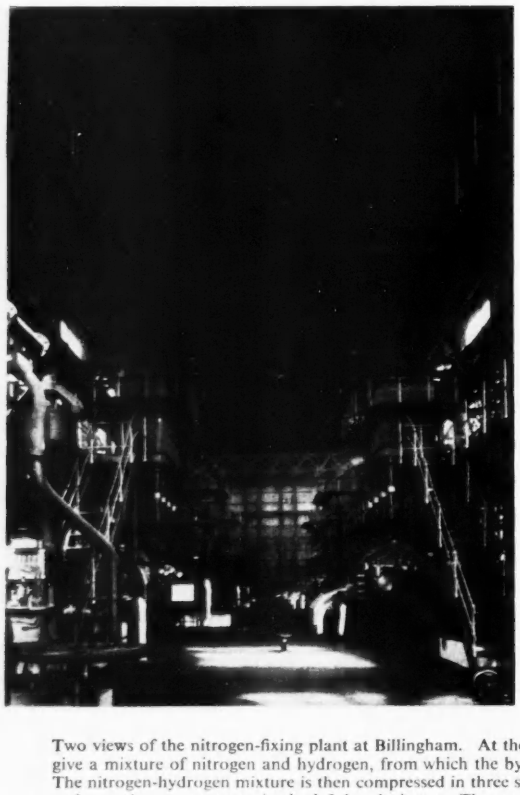
In the original expansion of the fertiliser idea (1843 to 1860 approx.) the principal nitrogen supplier was the 'natural' nitrate of soda imported from Chile. But the easy leadership which this material achieved was gradually displaced by the development of by-product sulphate of ammonia, and in time sulphate of ammonia became the dominant nitrogenous fertiliser, a position it has maintained ever since. Over a wide range of soil and weather circumstances, sulphate of ammonia could be described as the best nitrogen supplier for 'utility' purposes. At most times it has been the cheapest nitrogen supplier available. And although it is fairly speedy in action, it is less easily washed out of the soil than fertilisers whose nitrogen is already in the nitrate form when they are applied. The nitrate class of fertilisers require special rather than general conditions for displaying their full efficiency, e.g. application as top-dressings in summer.

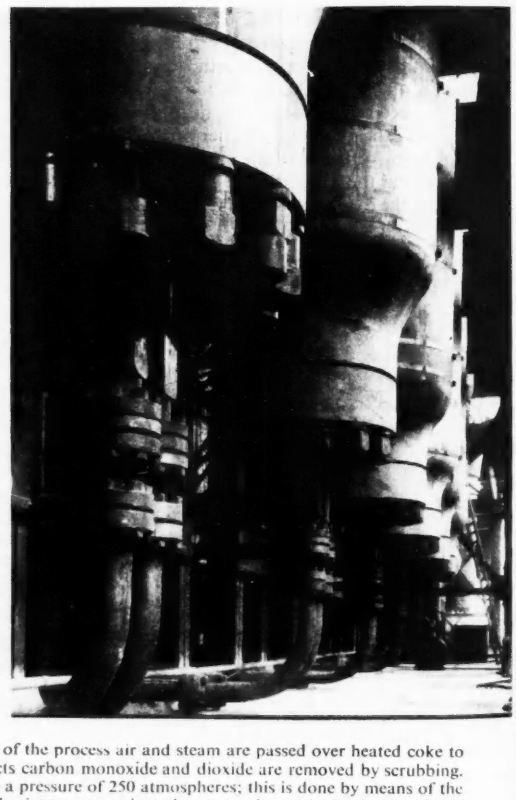
Although sulphate of ammonia has been the dominant vehicle for adding nitrogen to soils for so long, however, it is not free from disadvantages. It induces soil acidity. The ammonium ions are taken up by the plant, and the sulphate ions are left behind in the soil; these attach themselves to 'free' lime in the soil, thus accelerating the natural movement of the soil towards higher acidity. Wherever sulphate of ammonia is regularly used, more frequent attention to liming should be given. It is also considered by many agriculturists that high rates of sulphate of ammonia application lead to deterioration of soil structure—the build-up of residual sulphate ions has physical consequences of an undesirable kind. While these tendencies can easily be remedied for our present low rates of nitrogen application, they may present much more difficulty if the rates of nitrogen supply are significantly raised. Far more than for any other fertiliser nutrient, biochemical or biological processes are associated with the 'handling' of nitrogen. The form in which nitrogen is

*heavily* applied is likely to be a major factor in the success or otherwise of an intensified nitrogen policy.

In the United States there have been several new and alternate developments on a usefully large scale in recent years. The direct soil application of liquid ammonia and of strong ammonia solutions has been successfully established; combined solutions of urea and ammonia have also been used. (Very recently urea solutions have been sprayed on to foliage but it is too early to say whether this totally new approach to nitrogen feeding has general possibilities.) Most intensive growers have always preferred the insoluble organic nitrogen fertilisers, e.g. hoof and horn or dried blood, but today these natural materials can be imitated in their slow and steady action by synthetic nitrogen fertilisers based upon urea and formaldehyde. Urea and formaldehyde have long been joint partners in the chemistry of plastics. When these two molecules get together, they link up in long chains producing very large molecules; this is what is known as polymerisation and a variety of urea-formaldehyde substances can be made according to the conditions of reaction and the proportions of the two basic substances. It is now possible, under specific conditions and for certain ratios of urea and formaldehyde, to produce polymers which have fertiliser actions closely akin to those of hoof and horn, dried blood, etc. The Texas and French explosions of ammonium nitrate cargoes have prejudiced the development of this concentrated form of nitrogen, but urea, which is even more concentrated, is bound to receive increasing attention in future. It is at any rate quite clear that we need not think, as we have tended to think in the past, that nitrogen fertilising automatically means sulphate of ammonia. In an expanding future this fertiliser may play a rather less dominating part.

Nor, as a tail-piece, need every ton of synthetic nitrogen pass through the vegetable kingdom before it can be turned into animal protein. Urea can be used as a direct feeding-stuff for *ruminant* animals. Limited proportions of urea in the total feed are converted into protein by the animal without the intervention of plant photosynthesis. Though this development is in its very early infancy, an American technical journal this year estimated that as much as 50,000 tons of urea may eventually be used as supplement feeds for crops and sheep in the United States. We are only just beginning, after thirty years, to realise the enormous potentialities of synthetic fixation. For nitrogen is life and the only real answer to the problem of rising world population may lie in our ability to draw upon unlimited and universal reserves of nitrogen in the air.





Two views of the nitrogen-fixing plant at Billingham. At the outset of the process air and steam are passed over heated coke to give a mixture of nitrogen and hydrogen, from which the by-products carbon monoxide and dioxide are removed by scrubbing. The nitrogen-hydrogen mixture is then compressed in three stages to a pressure of 250 atmospheres; this is done by means of the reciprocating compressors in the left-hand picture. The compressed mixture passes into the ammonia synthesis plant (units of which are seen in the right-hand picture); here the nitrogen and hydrogen combine in the presence of red-hot iron oxide catalyst.

The ammonia produced passes on, to be fixed as ammonium sulphate, nitrate or carbonate, nitric acid or urea.

*(I.C.I. photographs.)*

# Far and Near

### Training Course in Scientific Film Appraisal

ONE of the Scientific Film Association's chief aims since its inception in 1934 has been the systematic appraisal of all scientific films and their grading for different types of audience.

To give practical training in Scientific film appraisal, the S.F.A. is holding a training course at Stone, Staffordshire, on Saturday and Sunday, September 24th and 25th, 1949. It is hoped to repeat the Course in other centres in the British Isles. The main object will be to train S.F.A. members and members of scientific film societies so that more appraisal panels may be set up, especially in the provinces and in Scotland; in particular it is hoped to interest representatives of learned societies and similar bodies so that they may appraise scientific films in their own fields by the S.F.A. method.

All enquiries for this and future courses should be made to the Secretary, Scientific Film Association, 4 Great Russell Street, London, W.C.1.

### Wanted: Bumble-bee Nests

A GLASGOW UNIVERSITY Scientist, Dr. A. D. Brian, wishes to enlist the aid of DISCOVERY readers in connexion with investigations he is making into the differences in feeding habits of the British Bumble-bees (*Bombus* sp.). This can be done quantitatively for any nest by pollen analysis of larval meconiums, since each larva on pupation ejects the residues of all food eaten during its larval life at the base of its cell, and these residues consist mainly of identical remains of pollen grains. Since each cell is only used by one larva and new cells are always formed above old ones, it is possible to determine from an old nest what pollens were eaten by the individual larvae at any stage in the growth of the nest.

For this purpose Dr. Brian needs a large number of nests of different species from different parts of the country, and he invites readers to send him any bumble-bee nests (consisting of brood, empty cells and honey pots) they may find, together with a few of the dead bees for identification, at: The Zoology Dept., The University, Glasgow, W.2. (Tel. 2231).

While is does not matter how old a nest is for the pollen analysis, it is advisable to dig nests up while they still have quite a number of bees in them, since in some species the nest itself may be a short distance along a mouse hole and is easier to find while bees are still coming and going. Dr. Brian draws attention to the fact that bumble-bees very rarely use their sting.

### National Research Development Corporation

THE six directors of the National Research Development Corporation (set up by the Government to develop inventions neglected by industry) have now been appointed. They are: Sir Percy Mills (chairman), Prof. P. M. S. Blackett, Mr. W. E. P. Johnson, Sir John Duncanson (formerly technical director of the Iron and Steel Federation), Sir Edward Hodgson (principal finance officer, Board of Trade) and Sir Edward de Stein. The Corporation's managing director, as announced in DISCOVERY in June (p. 199), is Lord Halsbury.

### Solvents from Petroleum

THE opening of the new £4 million Shell Chemical Solvents Plant at Stanlow in Cheshire, England, marks an important forward step in this country in the field of chemicals from petroleum, and will prove of considerable significance to the economy of the United Kingdom, quite apart from its importance in producing a range of raw materials of great value to many industries.

Incorporating advanced techniques, which have been accumulated during years of intense research and industrial application by the Shell Group in Europe and the U.S.A. since the early 1930s, the new plant will have an annual production of some 24,000 tons of various types of solvents.

Although these chemical solvents compete in certain industrial fields with those derived from other sources, the potential demand is vast and petroleum-derived chemicals—which have extensive uses in industries as diverse as paint and leather, food processing and photography—have certain technical advantages which should prove of great value, particularly to the surface-coating and allied industries. The wide range of chemical products from petroleum which may eventually be made should also render possible the establishment of new processes and thus assist in the advancement of the chemical industry in general in this country. The rate at which the demand has grown in the U.S.A. is remarkable, output during the past twenty years having roughly doubled every three years; and during 1948 some 2½ million tons of primary synthetic organic chemicals were produced from petroleum, representing about one-third of all the primary synthetic organic chemicals manufactured in the U.S.A.

Chemical solvents produced at Stanlow, from petroleum imported from sterling sources, will reduce U.K. imports of solvents from the U.S., which could represent an outlay of some $4 to $5 million per annum at present prices.

Although the Stanlow Plant was intended primarily to meet the demand at home, it is expected that a part of the production will be exported and will thus earn valuable foreign currency for the United Kingdom economy.

### An Electrostatic Clutch

AMONG the exhibits which Metropolitan-Vickers Electrical Co. Ltd. showed at the fourth annual exhibition held by the Institution of Electronics in Manchester on July 19–21 was an electrostatic clutch. A polished disc of high-resistance semi-conductor and a polished metal disc, both optically flat to $10^{-4}$ cms., are pressed lightly together. When a potential is applied between them, a force of attraction is developed approximately proportional to the square of the potential across the discs. This effect was first observed by Johnson and Rahbek using moist lithographic stone, an ionic semi-conductor. An electronic semi-conductor, unlike lithographic stone, is not dependent on moisture content and has, therefore, been substituted in the model.

A small clutch operating on this principle was exhibited driving a dynamometer and transmitting a torque of several hundred g.cm. The power consumption of the clutch is very low.

### Bee Research

A BEE research association has been established to promote, finance, organise and encourage research. Particulars of membership can be obtained from: the Hon. Secretary, Bee Research Association Ltd., 530–1 Salisbury House, London Wall, London, E.C.2. Communications on questions of research should be sent to the Director, Dr. E. E. Crane, 55 Newland Park, Hull, Yorks.

### B.C.G. Vaccination against Tuberculosis

ARRANGEMENTS have been made by the Minister of Health and the Secretary of State for Scotland for a start to be made shortly in using the vaccine known as B.C.G. as a protection against tuberculosis. This is not a form of treatment or a cure for the disease, but only a method of vaccination that may prevent a person from getting it. Experience alone will show how far it is effective under conditions in this country.

The time has not yet come for widespread or indiscriminate use of B.C.G., and for the present it will be used only within a defined scope and on the responsibility of tuberculosis specialists. It will consequently not be possible for this form of vaccination to be obtained by anyone going to his own doctor for it, though a doctor who may consider it advisable for a particular individual will be in a position to refer such a person to a chest physician with special knowledge and experience of tuberculosis.

The scheme that is at present in view will be in two main parts. B.C.G. vaccination will in due course be offered, subject to certain individual medical tests, to all hospital nurses and medical students as one among other precautionary inoculations that doctors and nurses commonly undergo against risks liable to be met with in their professional calling. This will be a big task, but it will be steadily proceeded with as quickly as the work can be done. Secondly, B.C.G. will be made available to chest physicians with special knowledge and experience of tuberculosis who may wish to give the vaccine to persons known to be in close contact with someone suffering from tuberculosis, always provided that such a person satisfies the preliminary medical tests.

### List of Scientific Abstracts

ARISING from a recommendation of the Royal Society Scientific Information Conference last year, a list has been compiled which contains, as far as they are known, periodicals and bulletins containing abstracts and published in Great Britain.

This list gives the most complete and up-to-date information on abstracts in Great Britain which has been published and will be of interest to scientists and libraries generally. The list is being sold at 2*s.* 6*d.* post free, through the Cambridge University Press, Bentley House, 200 Euston Road, N.W.1.

### Co-operative Bakery Research

THE British Baking Industries Research Station at Chorleywood, Herts., was officially opened on June 28 by the Duchess of Kent. For the support of the Station the industry has subscribed more than £30,000 to a Research Foundation Fund. The Research Station is directed by Dr. J. B. M. COPPOCK, F.R.I.C.

### Special Exhibition of Joule's Water-Friction Apparatus

ONE hundred years ago, in June, 1849, James Prescott Joule announced the results of extensive researches carried out in Manchester, in which he found that the expenditure of energy, in whatever form, was always accompanied by the production of a corresponding amount of heat.

From accurate measurements, Joule concluded that the quantity of energy necessary to raise the temperature of a pound of water by 1°F. was equivalent to that required to lift 772 pounds weight through a height of 1 ft. Translated into terms of everyday life, this means that to boil an average family-size kettle of water (capacity about 3 pints), a quantity of energy would be required which, in other circumstances, could be used to raise nearly 200 tons through a height of 1 ft.

Prior to Joule's experiments, there had been considerable disagreement among scientists concerning the nature of heat; some held it to be a material fluid (called caloric) which permeated the space between particles composing a hot body, whilst others attributed it to the mechanical energy of these same particles which were to be regarded as in rapid motion or vibration. Joule's work settled the controversy in favour of the second alternative, and thereby laid the foundation for our modern theory of heat.

The original water-friction apparatus with which Joule made an accurate determination of the mechanical equivalent of heat is preserved at the Science Museum.

### Veterinary Teaching at Cambridge

FOR the first time Cambridge is to embark on veterinary teaching. The University has agreed to seek powers under the Veterinary Surgeons Act 1948 to confer a degree in Veterinary Medicine that will be a registerable qualification and in October a limited number of veterinary students will begin a six-year course leading to this degree. The first three years will be spent in study for the Natural Sciences Tripos, and the following three years in professional studies. Plans are being drawn up for the erection of buildings for the new School of Veterinary Medicine, which will be situated within 2 miles of the centre of Cambridge on an area of approximately 120 acres of farmland. As with all courses in Cambridge, candidates must first be accepted for admission by a college and it is unlikely any college will accept for admission as a veterinary student an applicant who has not passed three of the four parts of the 1st M.B. Examination.

### Genetical Society's Hundredth Meeting

THE Genetical Society of Great Britain celebrated its hundredth meeting at Cambridge on June 30 and July 1 with invited lecturers and a practical review of current genetical and cytological research.

Dr. C. D. Darlington opened the meeting and introduced the guest speakers. Prof. R. C. Punnett, a pioneer of genetics in England, spoke of the early days of genetics and told of the difficulties which William Bateson experienced with his contemporaries and of his difficulty of getting genetical results published.

Prof. K. Mather was elected the new president of the Society to succeed Dr. E. B. Ford.

### LETTER TO THE EDITOR

#### School Biology

SIR,

In your comments in the May issue (pp. 135–6) on Professor Winton's address to the Science Masters' Association you suggest that University "departments such as . . . medicine . . . have little chance of influencing the school curriculum". In the case of the sixth form biology this is far from being the case. At present, in many schools, sixth form courses are dominated by the requirements of 1st M.B.

Further, in most cases, this examination encourages just those tendencies in school biology which Professor Winton deplores. The emphasis is very heavily on morphology and the comparative treatment of a small number of 'types'. Experimental methods receive little encouragement.

At present it is possible to evade this examination by obtaining exemption by means of a Higher Certificate. Here experimental methods have been introduced into the practical examination with success (see Punphrey, *School Science Review*, March 1949). But this examination has not the approval of the medical authorities (see the Goodenough Report) and will, in any case, disappear in the near future, when the qualifications for exemption from 1st M.B. will need to be redrafted.

Present-day conditions make it essential for most medical students to pass or obtain exemption from the 1st M.B. while still at school. The need for consultation between those who teach in the schools and those who teach in the universities is, therefore, urgent.

Yours, etc.,

B. W. H. COULSON,

2 Milton Road, Oundle,
May, 31, 1949.

### Building Research Board's New Chairman

MR. W. K. WALLACE, C.B.E., M.I.C.E., has been appointed Chairman of the Building Research Board in succession to Sir George Burt, M.I.C.E.

Mr. Wallace was appointed to the Board in 1940. Until his recent retirement he was Chief Civil Engineer to British Railways (London Midland Region). He was formerly Chief Engineer to the L.M.S. Railway, to which position he was appointed in 1933.

### Locust Outbreak Threatens East Africa and Middle East

EAST AFRICA and the Middle East are threatened by a new outbreak of the Desert Locust.

Swarms from Arabia have invaded the Aden Protectorate (area: 112,000 square miles) and the East African Desert Locust Survey is co-operating with officers of the Aden Department of Agriculture in a thorough-going offensive against them. Should the invasion not be smashed, the locusts may spread into British Somaliland, Ethiopia and Eritrea and thence into British East Africa.

Experts believe that the luxuriant vegetation which sprang up in Eastern Arabia after last winter's rainfall—the heaviest for 50 years—provided sufficient food to enable the locusts to swarm.

Planning the operations is Mr. P. R. Stephenson, Director of the East African Desert Locust Survey.

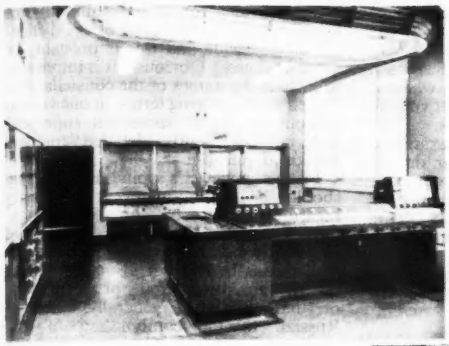
Motorised parties are being sent to the infested areas. The principal weapon they will employ against the locust swarms will be gammexane, a substance which kills locusts but is harmless to cattle, sheep and camels.

The technique used against the young locusts—the hoppers—is to spread bait (bran) which has been treated with gammexane. The poison is also sprayed from hand-pumps.

A five years' campaign against the Desert Locust ended only early last year when the 'all clear' was given by an expert conference at Nairobi, Kenya, headquarters of the East African Desert Locust Survey.

In this campaign, mechanised units were sent into all accessible areas where locust breeding was expected: into the deserts of Arabia, into Persia, Eritrea, the Sudan, Ethiopia, the Somalilands and Kenya.

In Arabia, with the help of King Ibn Saud, 300 cars and 1000 men took the field. Some of the seasonal campaigns



(*Above*) A typical workroom in the 'Hot' Laboratory. In the background is a fume cupboard for work with radioactive materials, left, glass-fronted store cupboards above lead-lined storage space. Suspended from the ceiling, centre, is a cylindrical ionisation chamber and, on the wall above the fume cupboard, an indicator for the measurement of radiation.

(*Above*) Harwell's Radiochemical Laboratory, now ready for partial occupation. The windowless first floor and the central raised block contain the main services and the ventilating system, which exhausts through the central square tower. To the right is seen the 200-ft. exhaust stack of the larger Harwell pile (BEPO).

in East Africa were waged by as many as 5000 men, with 500 cars.

The five years' campaign against the Desert Locust cost Britain about £1,000,000 a year—expenditure which was fully justified by the food supplies saved during that critical period. By taking prompt action and using modern methods of destruction, it is hoped to limit the cost of the present campaign to £25,000.

Pivot of the struggle against the three species of locust which plague Africa—the Migratory, the Desert and the Red Locust—is the Anti-Locust Research Centre established by the Colonial Office at the British Museum of Natural History, South Kensington. The Centre's funds are provided largely by grants made under the Colonial Development and Welfare Act. The Director is the world-famous authority on locusts, Dr. B. P. Uvarov, C.M.G. The Principal Scientific Officer is Dr. D. L. Gunn.

At this Centre there arrives, throughout the year, a constant stream of telegrams from the various 'fronts', reporting the latest news of locusts. Warning telegrams, based on this information, are sent to threatened areas, enabling the men on the spot to mobilise their forces to deal with any outbreak.

### 'Hot' Laboratory at Harwell Working

ONE wing of the new Radiochemical Laboratory at the Atomic Energy Research Establishment, Harwell, is now ready.

Announcing this, the Ministry of Supply says that the building is the most complicated project of its kind ever undertaken on this side of the Atlantic.

The laboratory will be used primarily for research on the chemical problems of separating the fissile element plutonium from uranium rods that have been irradiated in the pile. The rods also contain very radioactive 'fission products', and the chemical separation problem involved means that the scientists will be tackling one of the most difficult jobs in the Atomic Energy programme.

The laboratory will also be used for other chemical work with radioactive materials, including the separation of radio-isotopes produced in BEPO (British Experimental Pile), and processing materials that have been irradiated in the pile.

The type of work to be carried on in the laboratory means that entirely new problems—particularly regarding the health and safety of the worker and the control of any active material in dust, gases or effluent—will have to be tackled.

The building—designed to provide every facility for working with radioactive materials—is known at Harwell as the 'hot' laboratory.

In the centre of the ground floor is the administrative block. This consists of offices, laboratories, stores and workshops. Connected to it by air locks are two wings. These house the 'hot' laboratories. In the first floor, which is windowless, and the tower is a complex system that carries the main services and air ducts to the special ventilating plant. The operation of these is supervised in a central control room. There is reserve equipment to deal with any failure.

A hospital finish is used throughout the building and corners are rounded. Changing rooms and showers are provided for staff entering or leaving 'hot' areas, and foot-operated wash basins, with air-driers, are situated outside each laboratory group. Doors in 'hot' area corridors are automatically operated by photoelectric cells to reduce still further the risk of contamination from the hands. Equipment for 'monitoring' hands, clothing and body—that is to say, checking for radioactivity—is provided at washing places and an automatic monitoring system checks people leaving the building.

Active dust and fumes from the chemical processes are a possible airborne danger to health; the extraction system deals with this problem, while strict cleanliness minimises the dust. Dust-free air is admitted, and its flow, at maximum rate of some 360,000 cu. ft. per min. is distributed so as to extract any active dust and fumes. This maximum rate of flow is equivalent to 120 complete air changes per hour in a laboratory; though, under normal conditions, the rate will not exceed 40 changes per hour. Any active solids removed in this way are retained by precipitators so that the exhaust air leaving the central square tower is harmless. Similarly, all effluent through the drainage systems is segregated and monitored before final disposal.

Work with active materials will usually be carried out in ventilated fume cupboards where remote control of processes from behind walls of interlocking lead bricks may be used. Separate concrete-surrounded rooms are provided for work with highly radioactive materials.

All laboratories are continuously monitored so that the staff may know the amount of radiation to which they are exposed. Fire alarm and alarms for radioactivity risks are provided throughout, and the location of an alarm signal is recorded centrally.

### Haystack Fires

SPONTANEOUS combustion of agricultural products and industrial materials causes fire losses amounting in Britain to several millions of pounds a year. This hazard is described by Dr. J. B. Firth, Director of the Home Office Forensic Science Laboratory, North-West Area, Preston, in a paper published in *British Science News*, 1949, Vol. 2, No. 20, p. 226.

Hay is one of the most common agricultural products to undergo self-heating and destruction by fire. Any hay will fire given enough moisture and the right conditions. The safety limit is usually 25% of moisture; if the stack is wetter than that, it is likely to fire. Generally hay will not catch fire in less than 10 to 14 days or after a period of about 96 days after stacking; the majority of spontaneous stack fires occur 35 to 70 days after stacking.

Normally a stack that has undergone spontaneous combustion shows a gradual change from good to charred hay, namely, greenish-brown; golden brown; dark brown; chocolate brown; black carbon. The acidity increases with the degree of heating until charring begins, when the acidity drops, while completely charred hay is alkaline in reaction; the maximum acidity is in the dark-brown hay, where it is due mainly to acids that are not volatile —lactic, malic and succinic acids.

Samples from the stack when examined in the laboratory reveal whether or not the fire can be attributed to spontaneous combustion. For hay that has been directly fired the maximum acidity occurs in the dark-brown hay and has a maximum value of 2·5% calculated on the dry hay; in the case of spontaneously fired hay the values range from about 3·9% to 6·3% for dark-brown hay.

# The Bookshelf

**The Seashore.** By Professor C. M. Yonge, F.R.S.E., F.R.S. (London, Collins, 1949, 311 pp., 61 col. photographs, 62 black-and-white photographs, 88 text figures, 21*s*.).

THE aim of the New Naturalist series of publications is to interest the general reader in the wild life of Britain by reviving the enquiring spirit of the older naturalists. The editors of the series hold the belief—shared by this reviewer—that the natural pride of the British public in our native fauna and flora is best fostered by presenting to them, *with meticulous accuracy* and clarity of exposition, the results of modern scientific research and to portray animals and plants in the full beauty of their natural colours by the latest and best methods of colour photography and reproduction. In this book their aims are admirably achieved.

Of all the habitats in which living things are found none is richer than the seashore which is populated by an extraordinary wealth of life of astounding diversity and beauty; none, therefore, is harder to understand and explain scientifically or to portray pictorially. Professor Yonge —eminent biologist and accomplished author—has been fully equal to the demands made upon him by this vast and complex subject and has succeeded in producing a volume that is likely to be a standard text-book and *vade-mecum* for students and other serious workers for a long time to come. Because of its clarity and facility of exposition the book will prove equally attractive to the amateur naturalist and general reader with no previous knowledge of natural history.

Whatever its merits in other directions the attractiveness and even the value of a book of this kind to the general public and even—let us admit it!—to the serious student as well is immeasurably increased by adequate and well-chosen illustrations, especially in full natural colours. Here Professor Yonge has indeed been fortunate in obtaining the collaboration of Dr. D. P. Wilson who has provided the bulk of the illustrations. Dr. Wilson, himself a biologist of repute, is also without equal as a photographer of marine animals as one glance at the plates—both black-and-white and in colour—will abundantly confirm, in spite of the fact that in some of them the yellow tones are too pronounced. This, however, is due to the limitations of colour photography itself in its present state and is no fault of the photographer or of the reproduction. Prof. Yonge recognises and acknowledges how much the book owes to its illustrations. Not so the editors who, in their preface, extol the professor's high qualifications and literary attainments but omit even to mention the chief illustrator upon whom the success or failure of the book will depend in almost equal measure. Failure to allocate due credit to the illustrator is a mistake (a serious one) that is all too prevalent and ought to be corrected.

It is also important for editors to realise that in any publication that lays claim to scientific accuracy the illustrations should be treated with as much respect as the text and should not be 'improved' by 'touching up' unless the illustrator's permission has first been obtained. Had this precaution been taken by the editors of *The Seashore* the upper illustrations in plate XXX would not have been ruined by the addition of slender curved tips to the antennae of the Masked Crab, *Corystes cassivelaunus*—an addition that may have improved the photograph but which in real life would be disastrous for the crab. It is unfortunate, too, that the legends for three of the figures have become transposed; that of plate 25a rightly belongs to plate 38a; 25b to 25a; and 38a to 25b. Other errors and misprints in the book are exceptionally few and unimportant.

In recent years there has been a spate of popular natural history books many of whose authors seem to think that accuracy must be sacrificed to sensationalism in order to win popular approval. It is to be hoped that Prof. Yonge's book will provide a much-needed corrective for this mistaken and harmful belief.

G. A. STEVEN.

**Russian-English Scientific-Technical Dictionary.** Compiled and edited by A. Bray. (New York, International Universities Press; London, George Allen & Unwin Ltd., 551 pp., 50*s*.).

THIS dictionary is extremely well produced, a separate entry, printed in heavy type, being provided for each combination of Russian words. The scope of the dictionary is very wide and this is probably its main weakness. Obviously it is impossible to include the names of the constellations, as well as engineering terms, in one volume without making it somewhat superficial and not sufficiently detailed for any particular purpose.

In this reviewer's opinion a warning should be given in every dictionary regarding the use of words common to both languages. For example, it is not sufficiently clearly brought out that 'control' means in Russian primarily 'checking' or 'monitoring' and not 'regulation', or that 'grid-leak' generally refers in Russian to the combination of grid condenser and shunting resistance and not to the resistance alone.

The dictionary was published in 1945 and therefore the more recent terms such as 'wave-guides', 'radar', etc., are not included.

The above remarks should not detract from the value of the dictionary which is a definite contribution towards filling a gap that has been acutely felt.

**Greek Science: Its meaning for Us.** Vol. 2, Theophrastus to Galen. By Benjamin Farrington (Harmondsworth, Penguin Books, 1949; 181 pp., 1*s*. 6*d*.).

THIS long and eagerly awaited second volume fully lives up to the standard set by its predecessor (reviewed in DISCOVERY, May 1945, page 157). Here the main schools of scientists and philosophers to receive attention are the Lyceum after Aristotle, including Theophrastus and Strato; the Museum of Alexandria, including Ctesibius, Herophilus, Erasistratus, Euclid, Archimedes, Aristarchus, Hipparchus; and finally the men of the Graeco-Roman age, including Cicero, Lucretius, Vitruvius, Celsus, Pliny, Strabo, Ptolemy and Galen.

To list names, however, gives a false impression; for individuals are discussed by Prof. Farrington mainly in so far as they illustrate general trends in Greek thought. His object is to give a general picture of the nature of Greek science, its achievements and limitations, and of the elements in Greek life and society which made possible the achievements but imposed the limitations. To me the most interesting pages were those in which Professor Farrington clearly demonstrates that Strato put a heavy emphasis on experimental demonstration, and came very near to grasping the experimental method as a general method. There is much support here for the thesis, already developed in the first volume, that the experimental method arises when men with systematic, scholarly training take over and give orderly arrangement to the purely rule-of-thumb experimentation of the craftsman. And the chief cause for the limitations of ancient science is shown to lie in a social structure which except in brief and unstable periods forbade the scholar to learn from despised manual workers.

S. LILLEY.

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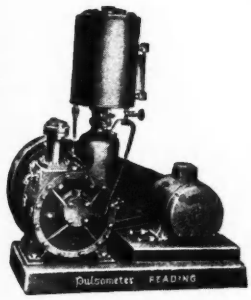


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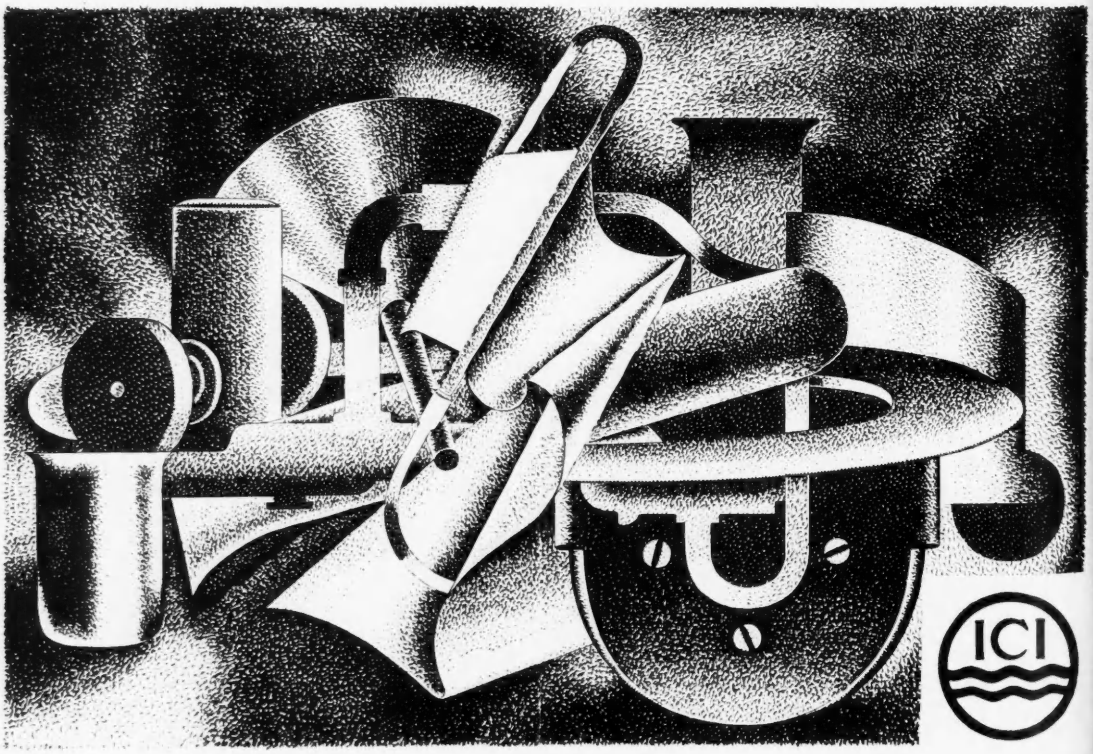

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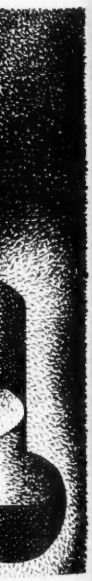

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